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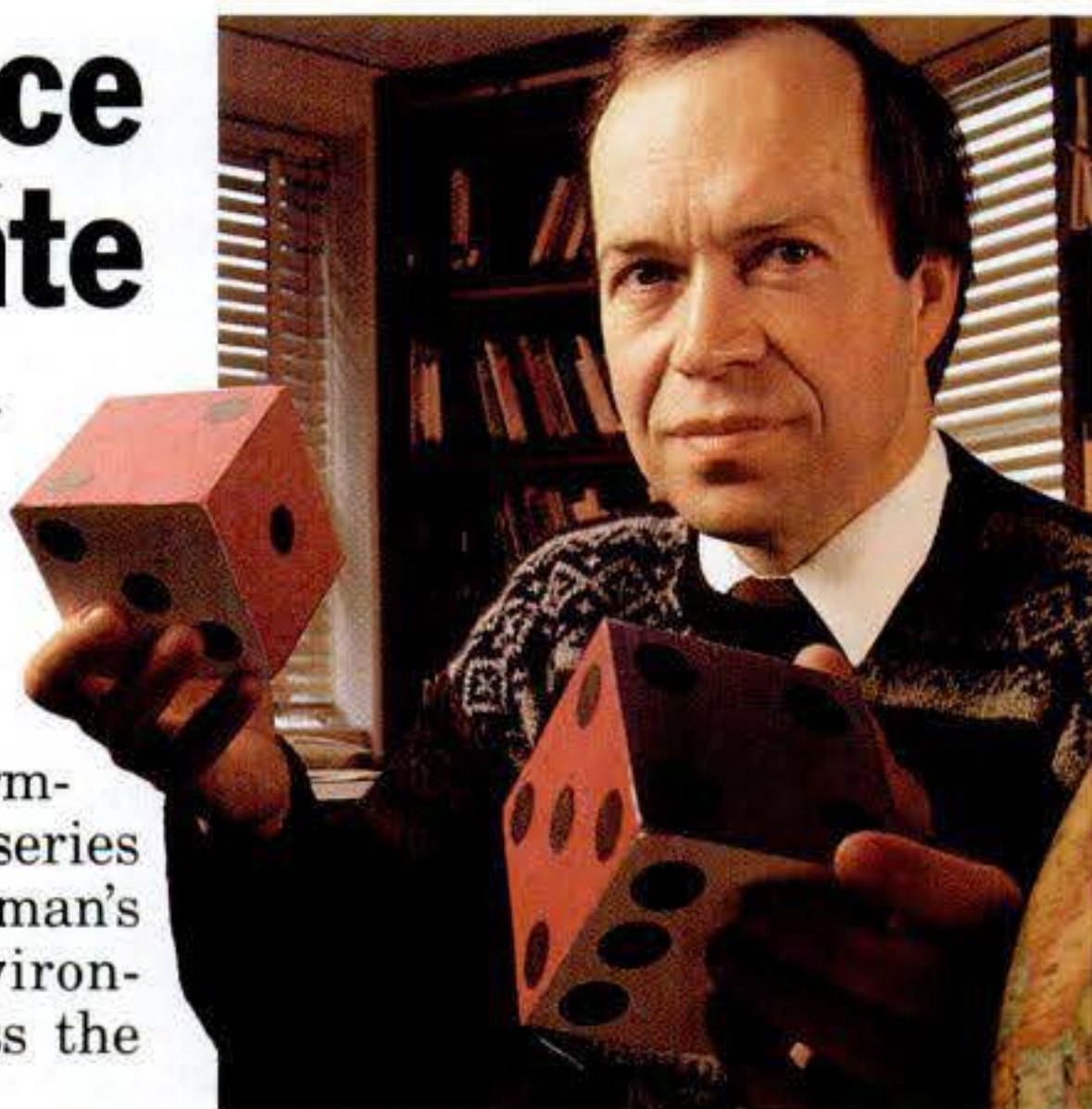
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Playing dice with climate

For more than 15 years climatologists have issued urgent warnings regarding Earth's changing climate. The problem: Mankind is accelerating the greenhouse effect. The result: global warming. Part I of this three-part series asks the experts to examine man's role in this worldwide environmental threat and to assess the nature of it. [Page 51](#)



Technology comes home

Sound-proof wood floors; exteriors with the look of stucco without its inherent problems. These innovative materials and more are presented in a collection of new home-improvement products. [Page 63](#)



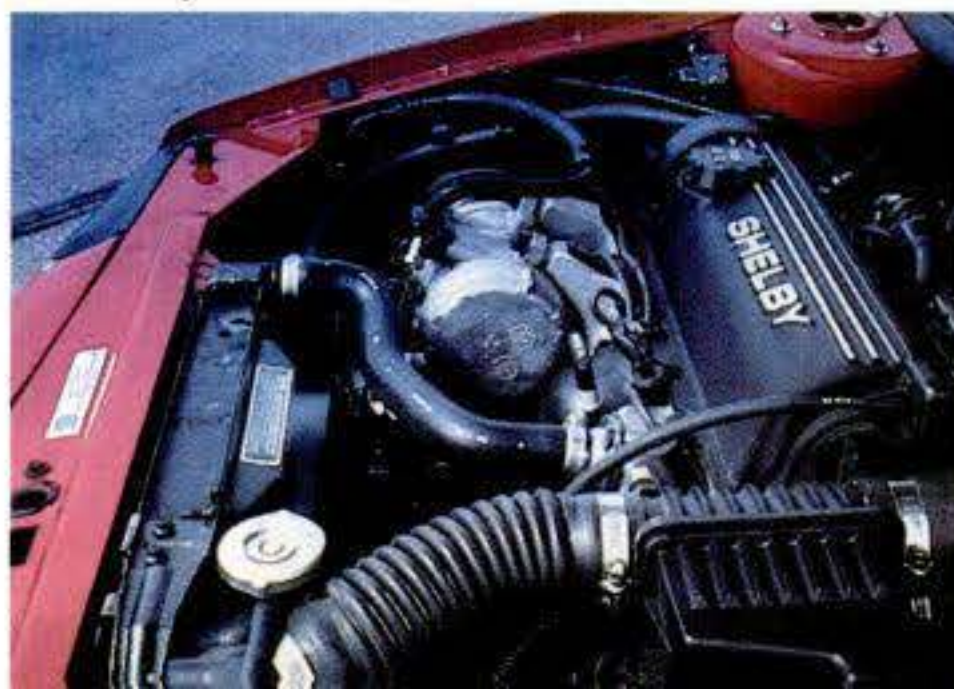
Tri-hull ship

This 104-foot prototype vessel sports a semi-submerged main hull, twin outer hulls, and a 17-foot bulbous bow. Its technologically advanced design may revolutionize the ship-building industry. [Page 60](#)



Turbo to go

The variable-nozzle turbocharger fitted to the 1989 Shelby CSX gears up against three other engines to see which responds quickest to the gas pedal. [Page 28](#)



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What's News

The greenhouse

In this issue you'll find an article by Science Editor Arthur Fisher on the much-talked-about greenhouse effect. In subsequent issues, two more episodes will follow. The first piece will give background on this crucial subject you may not have received from other sources, and will put into perspective the current state of knowledge on global warming. The second will go into the scientific evidence: how we know what we know, and where the evidence is too weak to make firm conclusions. The third and final episode will explore the alternatives available to us, and assess the importance of each and the likelihood of its being implemented.

If you are a regular reader of POPULAR SCIENCE, you know this is far more space than is usually given to a single topic. We chose to break with tradition in this case for several reasons. First, although the situation has been widely discussed on radio and television and in newspapers and news magazines, we believe that the scientific principles on which all conclusions are based have not been made available except in scientific journals and at scientific conferences. And second, the subject is certainly one of the most important before us. Until society understands the problems, including what we know for sure and where the areas of uncertainty lie, there is little chance that our democratic process can arrive at the right answers regarding what we can and should do. Also, we're going to have to make hard choices affecting our lives. Nowhere, for example, does this apply more than in the matters of...

Energy and the greenhouse

As the article documents in detail, there is no longer any serious debate on whether global warming has begun. The argument is now over what the magnitude of the effects will be and how fast it all will happen. Those two factors will determine the seriousness of the situation.

It's also widely agreed that the principal cause is that the carbon dioxide content of the atmosphere is rising because the world is burning ever more gas, oil, and coal. A complicating element is the cutting down of huge swaths of the world's forests to meet the needs

of expanding populations. That's important because plants help the situation by removing carbon dioxide from the atmosphere and giving off oxygen.

So what should we do? You know the answer. Our energy consumption not only continues to rise, but it is rising faster than production. We're becoming *less* efficient in using energy at the precise moment in the world's history when we should be *more* efficient.

That's particularly sad and foolish in view of our recent history. Starting in 1973 when we first became aware of the energy crisis, this country improved dramatically the efficiency with which we used energy. From 1973 to 1986, energy use stayed perfectly flat while the national output of goods and services increased 40 percent. Energy experts divide the total output of the economy in dollars into the total energy use in Btu. That gives a critical figure: the number of Btu used to produce a dollar's worth of goods or services. In 1973 the number was 27 Btu per dollar. By 1986 it had plunged to under 20. 1987 was level, then efficiency actually went *down* in 1988. It will decrease again in 1989.

As a result, energy consumption is now increasing faster than gross national product. In 1977 when President Carter made his famous speech urging us to make the quest to make saving energy "the moral equivalent of war," we imported 8.5 million barrels of oil a day. People responded; imports fell to 6 million barrels a day by 1981 and to 4.9 million in 1985. But oil prices collapsed in 1986, and oil importation quickly rose to its present level of 8 million barrels a day and climbing.

Reasons are easy to find. With prices low, most people aren't willing to spend money to increase the efficiency of such things as buildings and industrial processes. "People are not worried about being more efficient now," says Daniel Yergin, president of Cambridge Energy Research Associates. "There isn't a sense of urgency about it either."

It's not as though there wasn't room for improvement. We use twice as much energy per capita as the Japanese, for example. There are lots of reasons. Our houses are larger, and we heat them to much higher temperatures. (Many Japanese find winter indoor temperatures in the low-sixties satisfactory.) We have comparatively huge refrigerators

Continued

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and freezers. We made good progress in insulating our houses over the last two decades, but they could be better—a lot better.

Improvements in the industrial use of energy were significant during that period we were reducing our Btu-per-dollar figure. But now, with energy abundant and relatively cheap again, there is far less incentive.

Finally, over the last decade we've decided we don't want any more nuclear power in this country, despite the fact that nuclear power can generate electricity without burning fossil fuels, and thus does not contribute to global warming. I don't want to get diverted by the nuclear controversy right now—POPULAR SCIENCE will be tackling that soon—except to point out that deciding against nuclear aggravates the global-warming problem.

Now let's get personal

Despite all the foregoing, most of us have rekindled our love affair with big, fast, powerful cars. Under the impetus of the energy crisis, new-car mileage went from just over 16 mpg in the early 1970s to nearly 29 in recent years—a dramatic improvement. But the impetus has been lost. The Reagan administration, at the urging of much of the auto industry, which, of course, was simply responding to the demand of its customers, cut the mandated Corporate Average Fuel Efficiency (CAFE) figures from the 27.5 mpg the auto makers were supposed to reach by 1985 to 26 mpg for 1986, '87, and '88 with a rise to 26.5 in 1989. Now, in response to rising concern about the increasing threat of a runaway greenhouse, the Bush administration has mandated that a CAFE standard of 27.5 mpg go into effect with 1990 models.

To date, at least five bills have been introduced in Congress to mandate increasingly severe mileage standards, several of which would require CAFE to rise to between 40 and 50 mpg by the year 2000. Backers point out that 30 percent of the carbon dioxide produced in this country comes from the tailpipes of cars, and there's only one way to do anything important about it.

The auto industry, for the most part, remains strongly against any tightening of CAFE standards. And there is no argument that big changes in the standards would be expensive. Designers and engineers are already working on 1994 cars, and big changes would mean big bucks. Such a turnabout in what amounts to six years would, in the words of one Chrysler official, "take at least \$1.5 billion per car line at a

time when the economy could be heading into a recession." Also, car makers are planning to meet what appears to be an insatiable demand on the part of the public for bigger, more powerful cars and engines in the mid-1990s. Much of that planning would have to be thrown out to meet tougher CAFE standards, and the paying customers would have to accept the smaller cars they're obviously not keen about.

There are other methods that could be used to get at the problem. One suggestion made repeatedly is simply to increase gasoline taxes significantly. That would help ease the towering federal deficit, reduce the balance-of-payments squeeze, and greatly increase the demand for small, high-mileage cars. This is the approach that has worked in both Europe and Japan, where gas prices range around the \$3-per-gallon area. Thus market forces rather than government edicts would be harnessed. "If you want to raise fuel standards significantly above 27.5 mpg," says Chrysler Chairman Lee Iacocca, "you need two things. We need at least five years of lead time. We are finished with the 1991 and 1992 models. And we need some consumer pull in the form of a gas tax. They've got to get the consumers to demand those types of vehicles just as they do in Europe and Japan." Iacocca points out that with gas above \$3 a gallon there is no need for fuel-economy laws. The demand for small cars is strong.

But while the mechanism is far from being set, most observers think *something* is likely to happen soon. "If we have another very hot, dry summer and the TV, newspapers, and magazines start screaming, 'The greenhouse effect is here, somebody do something,'" says Chrysler President Robert Lutz, "well, the somebody will be Congress, and they will increase CAFE."

To car owners and drivers—and that includes practically all of us in this prosperous country—none of the alternatives offers a pleasant prospect. "I like to drive fast and have a high-powered car," said Lodwick M. Cook, chairman of ARCO. "But it's bad public policy."

He's right. While it is undeniably fun to drive fast cars, we also have to live on this planet. We'll all be facing some hard choices in the coming years and decades.



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Published monthly by
TIMES MIRROR MAGAZINES, INC.
2 Park Ave., New York NY 10016
ISSN 0161-7370

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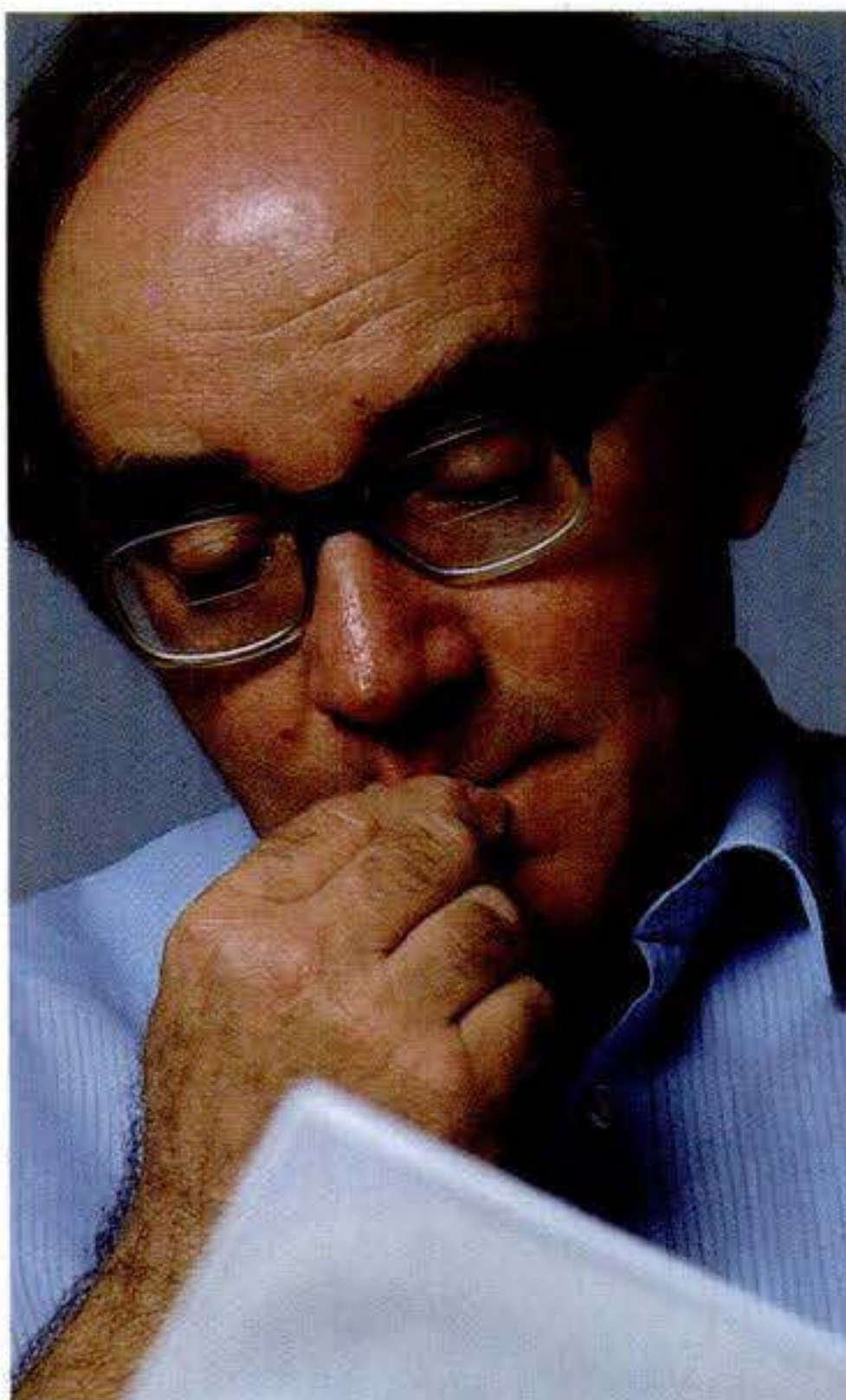
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Science Newsfront

By ARTHUR FISHER



Buffeted by conflicting reports on their cold-fusion claims, these three scientists are continuing to experiment with elec-



trolytic cells containing palladium electrodes. They are Stanley Pons of the University of Utah, left; Martin Fleisch-



mann of the University of Southampton, England, center; and Steven Jones of Brigham Young University.

Fusion fizzle?

"May you live in interesting times" is an old Chinese curse, not a benediction; such times are generally not tranquil ones. Recent months certainly have not been easy for the individuals pictured above, nor for the thousands of other scientists trying to replicate their experiments. The objective is cold fusion—nuclear fusion at room temperature rather than at many millions of degrees. (See *Furor Over Fusion*, "SNF," June.)

From left to right, the three men are Stanley Pons of the University of Utah in Salt Lake City; his collaborator, Martin Fleischmann of the University of Southampton, England; and Steven Jones of Brigham Young University in Provo, Utah. Both groups claim to have observed cold fusion of deuterons in a palladium electrode immersed in heavy water undergoing electrolysis, as described in June's column. (Deuterium is a heavy isotope of hydrogen; heavy water is deuterium oxide.)

But it is essential to remember that the similarity stops there. Pons and Fleischmann report the generation of excess heat far beyond energy break-even—as much as 5,000 percent in

one trial. They say their work portends a new era of abundant, non-polluting power that will free the world from dependence on fossil fuels. At an April 26 hearing before the House Committee on Science, Space and Technology, University of Utah President Chase N. Peterson asked for federal funding of \$25 million for this research.

Jones, however, reports an energy output, in the form of neutrons, about a trillion times less than the University of Utah team. At the same Congressional hearing, Jones maintained that "cold fusion does not offer a shortcut to fusion energy."

Just what are the prospects for cold fusion as a practical source of energy? They're a lot colder than when the Pons-Fleischmann announcement first stunned the scientific world. The initial skepticism first generated on purely theoretical grounds has escalated drastically as most—though not all—experimenters failed to duplicate the Utah results. And the ongoing debate has turned nasty to a degree unsurprising to those familiar with past examples of scientific internecine warfare.

Some of the interdisciplinary sniping began at a Dallas meeting of the American Chemical Society on April

12, when 7,000 chemists trooped into a sports arena to hear a special session on cold fusion, a session that cast the Pons-Fleischmann results in a rosy light. In his introduction, Clayton F. Callis, president of the ACS, said it was about time chemists, and not just physicists, were getting the spotlight attendant on a breakthrough discovery—an obvious allusion to the excitement over high-temperature superconductors two years before. The audience of chemists roared and clapped their approval.

That was probably the high-water mark for the Salt Lake work. In the first frantic weeks following the initial Pons-Fleischmann press conference, with everyone from graduate students to heads of departments losing sleep in an effort to join the fusion bandwagon, there had been a flurry of tantalizing reports of confirmation, most somewhat tentative. They came from such stalwarts as Texas A&M, Georgia Tech (but the Wrecks quickly retracted their results because of a belatedly discovered instrument error), and Stanford University. In no case was there a definitive claim that fusion was taking place in the electrolytic cells, just something anomalous, whether excess heat or neutrons.

Then, on May 1, came a heavy deluge of cold water. The American Physical Society held its own special session on cold fusion in Baltimore, and a procession of physicists trashed the Pons-Fleischmann results on a variety of grounds. The speakers included representatives of such heavy hitters as Lawrence Berkeley Laboratory, MIT, Brookhaven National Laboratory, Oak Ridge National Laboratory, Rochester University, and Yale University.

Probably the most damaging assault came from a California Institute of Technology team. Physicist Steven E. Koonin said, "Our theoretical studies indicate that the Brigham Young University results are quite improbable, but perhaps not impossible. However, we know of no way of accounting for the University of Utah results The experiment is wrong." And lamenting the thousands of hours of time and some million dollars of research money that had been poured into the effort to replicate the Salt Lake work, Koonin said, "We are suffering from the incompetence and perhaps the delusions of professors Pons and Fleischmann."

And the most unkindest cut of all came from Caltech's Nathan Lewis, not a physicist, but a member of the electrochemical fraternity itself. He dissected four key observations the Salt Lake researchers claimed were signals of fusion: the presence of excess heat, tritium, helium, and gamma rays. After weeks of recording data from dozens of experiments with highly sophisticated equipment, he said, Caltech researchers were unable to detect any of these signals. Moreover, he pointed to specific sources of error in the Pons-Fleischmann work and other efforts to replicate it that could have resulted in false results. Poor calorimetry and a failure to mix the electrolyte (resulting in hot spots), for example, could account for the readings of excess heat. And the gamma-ray spectrum obtained did not match one that should have been produced by fusion neutrons, but was rather the signature of radon gas, a daughter product of uranium and a naturally occurring element that would be unsurprising in a Salt Lake City laboratory. Other errors, Lewis said, disposed of the occasional reports of helium and tritium.

When Yale physicist Moshe Gai was asked whether he was ready to issue a death warrant for the Pons-Fleischmann results, he replied, "You have it."

Pons and Fleischmann had a chance to respond a week later in the presumably hospitable bosom of a meeting of the Electrochemical Society in Los Angeles. Indeed, the Society had spe-

cifically invited contributions to a special session on cold fusion from "research groups who have verified the initial reports"—an unusual limitation. Furthermore, science journalists, originally barred altogether from the technical sessions, were forced to fork up \$205 as a registration fee.

Despite the fact that Pons and Fleischmann had promised to present important new experimental results to buttress their remarkable claims, none were forthcoming. Instead, they backtracked on some earlier statements, conceding that their gamma-ray spectrum was probably wrong because of inadequate equipment.

"I have always been ready," Fleischmann said, "to acknowledge that our experiments may be faulty. If we turn out to be wrong, I'll be the first to admit it."

Pons and Fleischmann also agreed with critics that the most incontrovertible test of nuclear fusion would be the detection of helium-4—formed from the merging of two atoms of deuterium—inside the palladium electrodes. Failure to find this signal, Fleischmann said, "would eliminate a very substantial part" of the basis for their cold fusion claims. But when representatives of MIT and Sandia National Laboratories challenged the Salt Lake team to submit tiny samples of the electrodes for instant analysis ("We'll get the report back to you within three days," one said), Pons and Fleischmann declined on the grounds that they had

**"Cold
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plex and most
elusive"**

arranged for such a test to be done by another organization, which they refused to name.

Some laboratories, including those at Stanford and Texas A&M, reported getting anomalously high heat output in their experiments, and stoutly defended the Pons-Fleischmann energy claims, although they were unable to conclude that cold fusion was actually at work. There were also scattered and hard-to-confirm reports of excess neutrons—barely above the natural background—from elsewhere around the world, including North Korea's Kim Il Sung University. These neutron observations, even if correct, were a billion to a trillion times too small to accord with the excess energy reported by Pons and Fleischmann. Still, there seemed to be enough uncertainty to keep scientists busy.

"I wouldn't continue to carry out these experiments if I thought cold fusion was absolutely impossible," Charles Barnes, a Caltech nuclear physicist, told me at the Los Angeles meeting. "There are still things we have to try before we can rule it out absolutely. It's very hard to prove a negative."

As this is being written, the fourth in a series of tumultuous meetings on cold fusion has just ended, and the "interesting times" for Pons and Fleischmann, who were conspicuous by their absence, may be over. At the request of Energy Secretary Admiral James D. Watkins, Los Alamos National Laboratory convened a three-day international workshop in Santa Fe, N.M., May 22 to 25. Siegfried S. Hecker, director of the Los Alamos lab, led the proceedings by saying that "Cold fusion, if it exists, has turned out to be very complex and most elusive."

The outcome for the Pons-Fleischmann work—and thus for the golden prospects of practical room-temperature fusion—was negative. The hammer blow came when John Appleby, director of Texas A&M's center for electrochemistry, reported that no helium could be found in palladium electrodes that had produced excess heat. The painstaking analysis had been carried out by the Atomics International Division of Rockwell. There were still mysteries, including the origin of heat some researchers were observing, and the appearance of excess tritium in the Texas A&M cells. But few of the attendees believed that cold fusion on the Pons-Fleischmann scale was occurring.

"I personally do not believe that the Pons-Fleischmann heat is due to anything but chemical energies," said co-chairman J. Robert Schrieffer. Schrieffer

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Americans go with the truck leader. For the past 12 years, Americans have chosen tough Ford pickups over all others.* And they're satisfied with their choice — because Ford has the highest percentage of *repeat* buyers of any full-size pickup!** Last year Ford's F-Series pickups beat Chevy again by a big margin.

BIGGER ENGINE, MORE TORQUE!

Ford's pickups offer a bigger stan-

dard Six — with 10% more torque than Chevy. V-8s range from most powerful small gas V-8 to biggest diesel in *any* pickup. Only Ford pickups offer four multiple-port electronic fuel-injected engines. When properly equipped, some Fords are rated to tow a 12,500-lb. trailer.

COMFORT, CAB CHOICE.

Ford offers a complete range of cab choices. There's a Regular



Cab, SuperCab and 4-dr. Crew Cab — with single or dual rear wheels.

BIGGER CARGO BOX, MORE PAYLOAD.

Ford gives you a larger, wider, deeper pickup box than Chevy.



Buckle up — together we can save lives.

On many models, Ford carries more maximum payload than comparable Chevys.

AUTOMATIC LOCKING HUBS — STANDARD!

Now on Ford F-150 4x4s! Fords also come with standard equipment the Chevy C/K doesn't. Features like halogen headlamps, AM radio with digital clock, and four gauge package.

All big Ford pickups have gas-pressurized shocks standard — for a smoother ride on-road or off. Ford was first with rear Anti-lock brakes, aerodynamic styling, and 4x4 Twin Traction Beam independent front suspension.

SPECIFICATIONS

ENGINES

145-hp. 4.9L EFI Six
185-hp. 5.0L EFI V-8
210-hp. 5.8L EFI V-8
230-hp. 7.5L EFI V-8
180-hp. 7.3L diesel

PAYLOADS

F-Series 4x2 pickups:
1575 to 5270 lbs.
F-Series 4x4 pickups:
1750 to 4295 lbs.

CABS

Regular 3-Man Cab
Ford 2-Door SuperCab
Ford 4-Door Crew Cab

MAJOR STANDARD

EQUIPMENT

Power brakes
Power steering
5-speed OD transmission
Gas-pressurized shocks
Electronic radio & clock
Full instrumentation

TRANSFERABLE 6/60 WARRANTY.

Covers you and future owners, with no transfer cost, on major powertrain components for 6 years/60,000 miles. Restrictions and deductible apply. Ask your Ford Dealer for a copy of this limited warranty.

BEST-BUILT AMERICAN TRUCKS 8 YEARS RUNNING.

Based on an average of owner-reported problems in a series of surveys of '81-'88 models designed and built in North America. At Ford, "Quality is Job 1."

Now's the time to buy or lease.

*Based on calendar year manufacturers' reported retail deliveries through 1988.

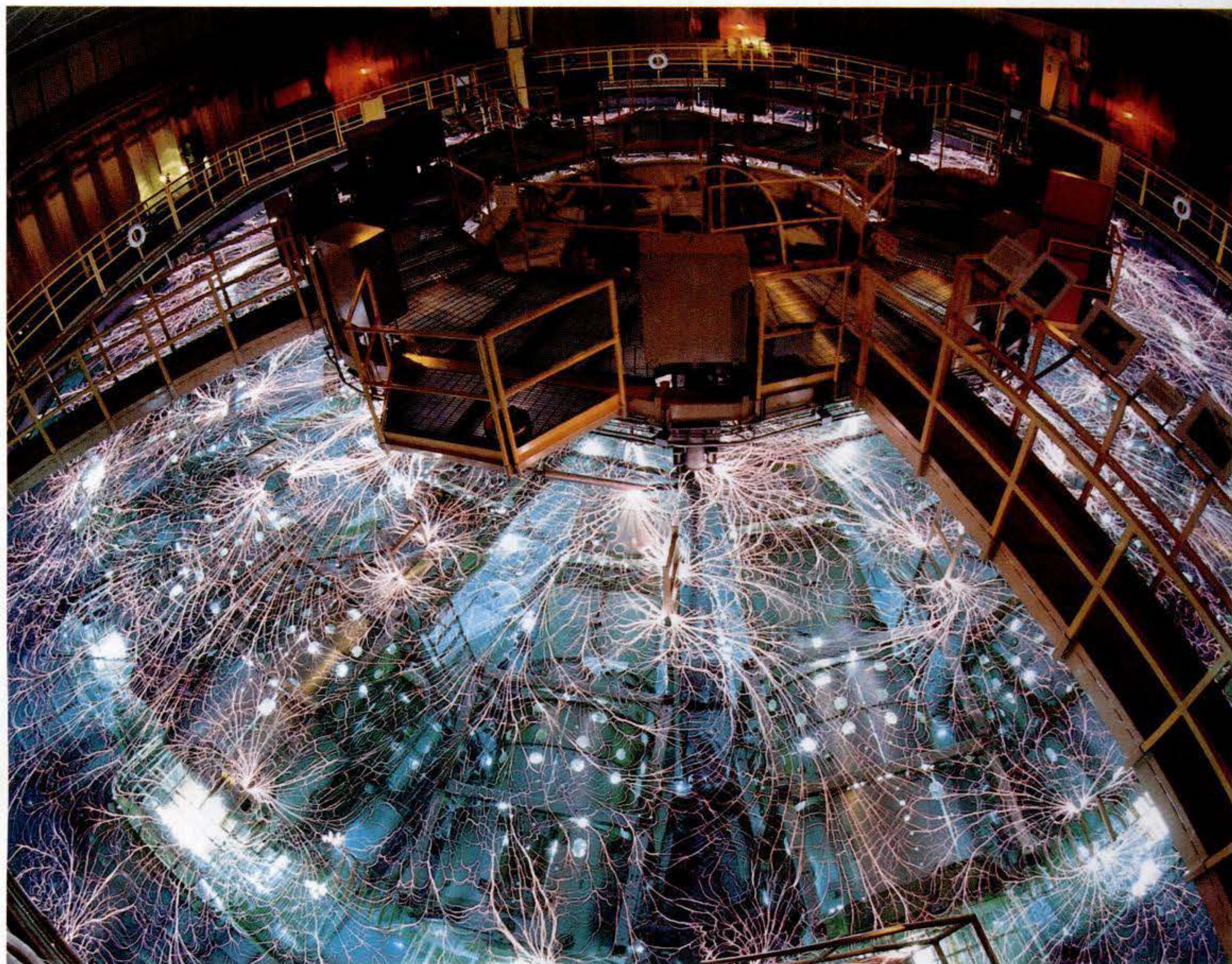
**Based on 1988 New Car And Truck Buyer Study.

GO WITH THE LEADER



FORD PICKUPS

BUILT FORD TOUGH



Sandia Laboratories' Particle Beam Fusion Accelerator II makes a key advance in the search for inertial confinement fusion.

fer is director of the Institute for Theoretical Physics at the University of California at Santa Barbara.

The news for Steven Jones was somewhat more encouraging. The Brigham Young University physicist's claims for cold fusion at a level a trillion or so times smaller received support from three groups: the National Institute of Nuclear Physics in Italy; Texas A&M; and Los Alamos National Laboratory itself. All three used palladium or titanium rods and reported excess neutrons at levels consistent with the modest BYU results. "Things keep turning up roses," Jones beamed.

Even these unsensational claims, however, were contested by Yale's Moshe Gai. The ultrasensitive apparatus used in the Yale-Brookhaven collaborative experiments had failed to detect any neutrons above background level from a carefully constructed duplicate of the BYU cold-fusion cell.

No major meetings on cold fusion are planned until the Electrochemical Society meets again in October.

Particle beam progress

Speaking of fusion, physicists at Sandia National Laboratories in Albuquerque, N.M., have notched another step up the ladder toward one of the two conventional hot-fusion goals: inertial confinement fusion. That method entails zapping a fuel pellet containing either deuterium or a mixture of deuterium and tritium with a ferociously intense laser beam or a stream of high-energy particles. The idea is that the fuel's own inertia keeps it from dispersing until the necessary conditions—confinement time, density, and temperature—are reached, and thermonuclear ignition occurs. (The other hot-fusion method is magnetic confinement, in which a hot plasma is constrained in some kind of magnetic "bottle.")

At Sandia, the giant Particle Beam Fusion Accelerator II pictured above has generated a proton beam of unprecedented intensity, with 35 times more energy carried by the particles than from any other accelerator. The power

density equivalent was 5.4 trillion watts per square centimeter.

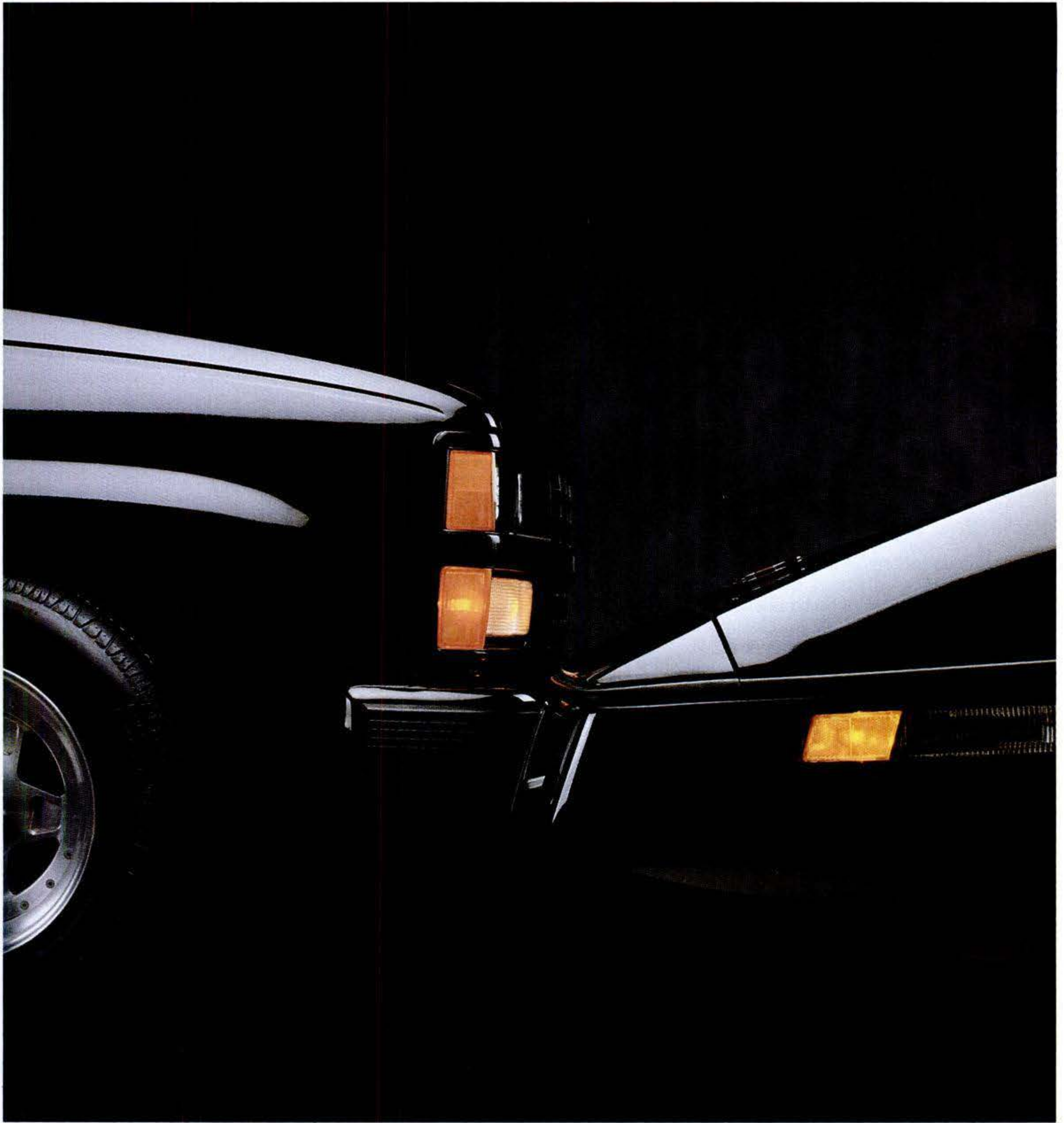
Exercise benefits

A study begun in the late 1950s using a pool of more than 3,000 men demonstrates that even light physical exercise has a beneficial effect on health in general and affords significant protection from heart disease. The results of the study appeared in the February issue of *Circulation*, the journal of the American Heart Association.

How light is light? Walking 10 minutes a day on a level surface at a pace of three mph expends a trivial 250 calories per week. Yet even that amount, compared with a sedentary lifestyle, protects against death from heart disease and other illnesses. Says Martha L. Slattery of the University of Utah Medical School, one of the report's authors, "Any kind of physical activity will probably protect against heart disease."

Overweight people, however, should be wary of stair-climbing. **PS**

OUR PREMIUM GIVES YOU MORE MUSCLE NO MATTER WHAT SHAPE YOU'RE IN.



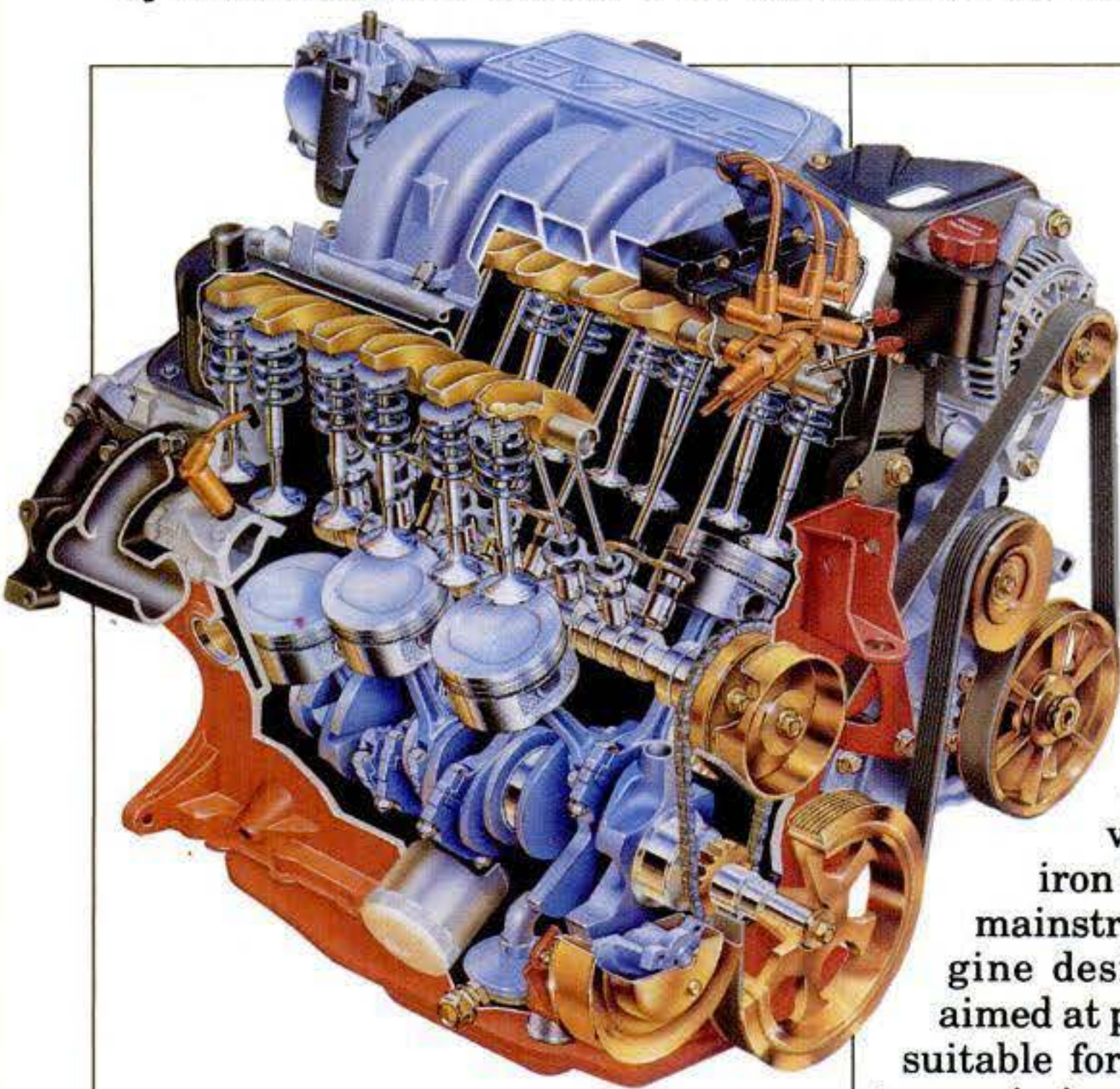
If you want more muscle in your car, forget about your old routine. Pump up to the gasoline that eliminates knocks, pings and hesitation while it cleans fuel injectors. Phillips 66 SuperClean® Premium Unleaded. Performance power from Phillips 66.

PUMP UP TO SUPERCLEAN® PREMIUM.

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Automotive Newsfront

By **DAN McCOSH** Detroit Editor with David Scott in France and Brian Nadel in Madison, Conn.



Chrysler's first home-grown car engine design since the corporate four-cylinder unit is this 3.3-liter V6. A proven pushrod valve train is combined with an even firing sequence to produce 150 hp at 4,800 rpm and 185 lb.-ft. of torque at 3,600 rpm.

white line. Its basic 60-degree layout, pushrod valve actuation, and cast-iron block put it solidly in the mainstream of contemporary engine design. The technology is aimed at producing low-end torque suitable for use with an automatic transmission. The torque curve is flat as a pool table, and 90 percent of peak power is available between 1,600 and 4,800 rpm, according to Chrysler engineers.

The 60-degree architecture offers the benefit of even firing, and also fits neatly in the transverse-engine-

mounting layout common on front-drive cars, which form the lion's share of Chrysler's product line. Internally, the engine has two-valves-per-cylinder heads and two squish areas to control burn rate, and operates on an 8.9:1 compression ratio with regular unleaded gasoline.

Most striking is the new distributorless ignition system, which picks up timing signals from both the crankshaft and camshaft. The engine also features multi-port fuel injection—a sign the stopgap throttle-body-fuel-injection days might be numbered. Chrysler engine designers have left room to update the engine with overhead-cam versions, four-valve-per-cylinder heads, and turbocharging, plus larger displacement units.

The new Chrysler V6 clearly is the starting point of a larger family of engines to follow.

Yesterday, today

With other manufacturers stretching the performance envelope, Chrysler Corp. seems content to fill the middle of the box with its engine designs. Most of Chrysler's 1960s-vintage high-performance "hemi" engines now are museum pieces, and the home-grown corporate lineup still relies extensively on four-cylinder power plants for passenger cars.

Up to now, V6 car engines have come from abroad: Mitsubishi supplying those for Chrysler, Dodge, and Plymouth, and Renault for the Eagle line. Now comes Chrysler's first all-new car engine design since the corporate four-cylinder unit that was introduced in 1981 and today powers 62 percent of its products in both standard and turbocharged form.

At first glance, the new 3.3-liter V6 is as middle of the road as a double

Integra grows up

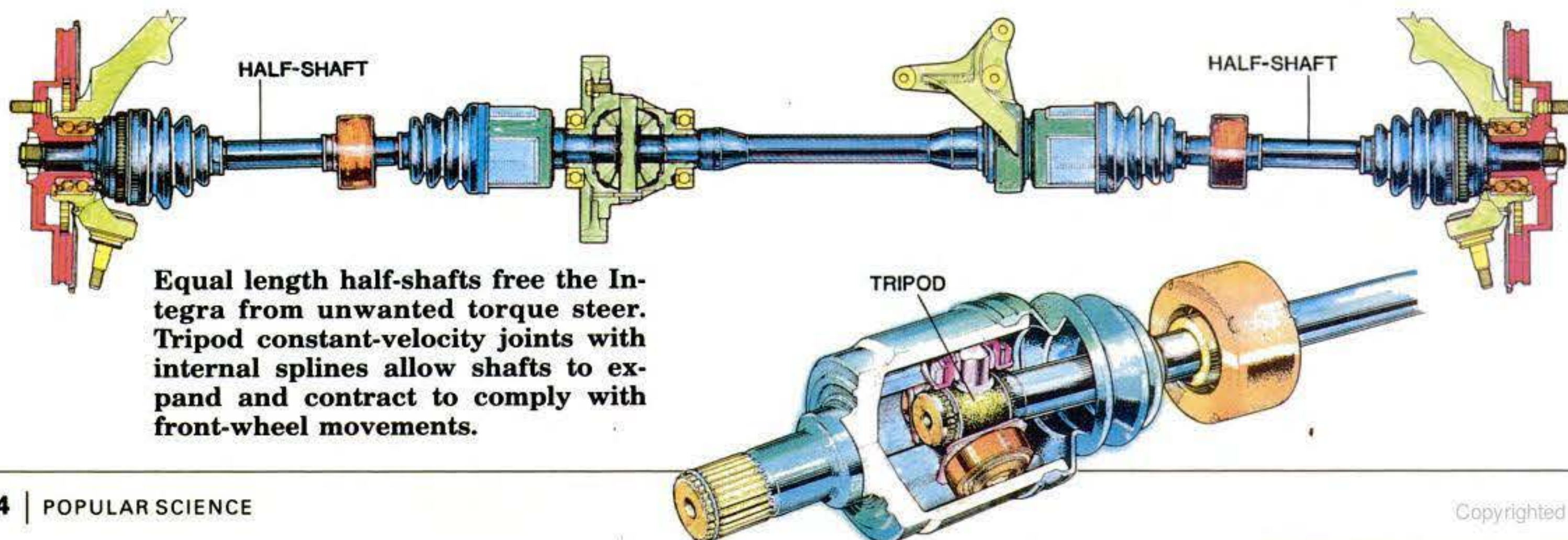
The 1990 Acura Integra is longer, lower, wider, and more powerful than its predecessor, but is not as technologically up to date as the model offered

HERB SHULDINER



The 1990 Acura Integra is longer, lower, and wider, and contains no carry-over parts from the car it replaces. The

three-door hatchback is shown above; a slightly longer four-door notchback sedan is also available.



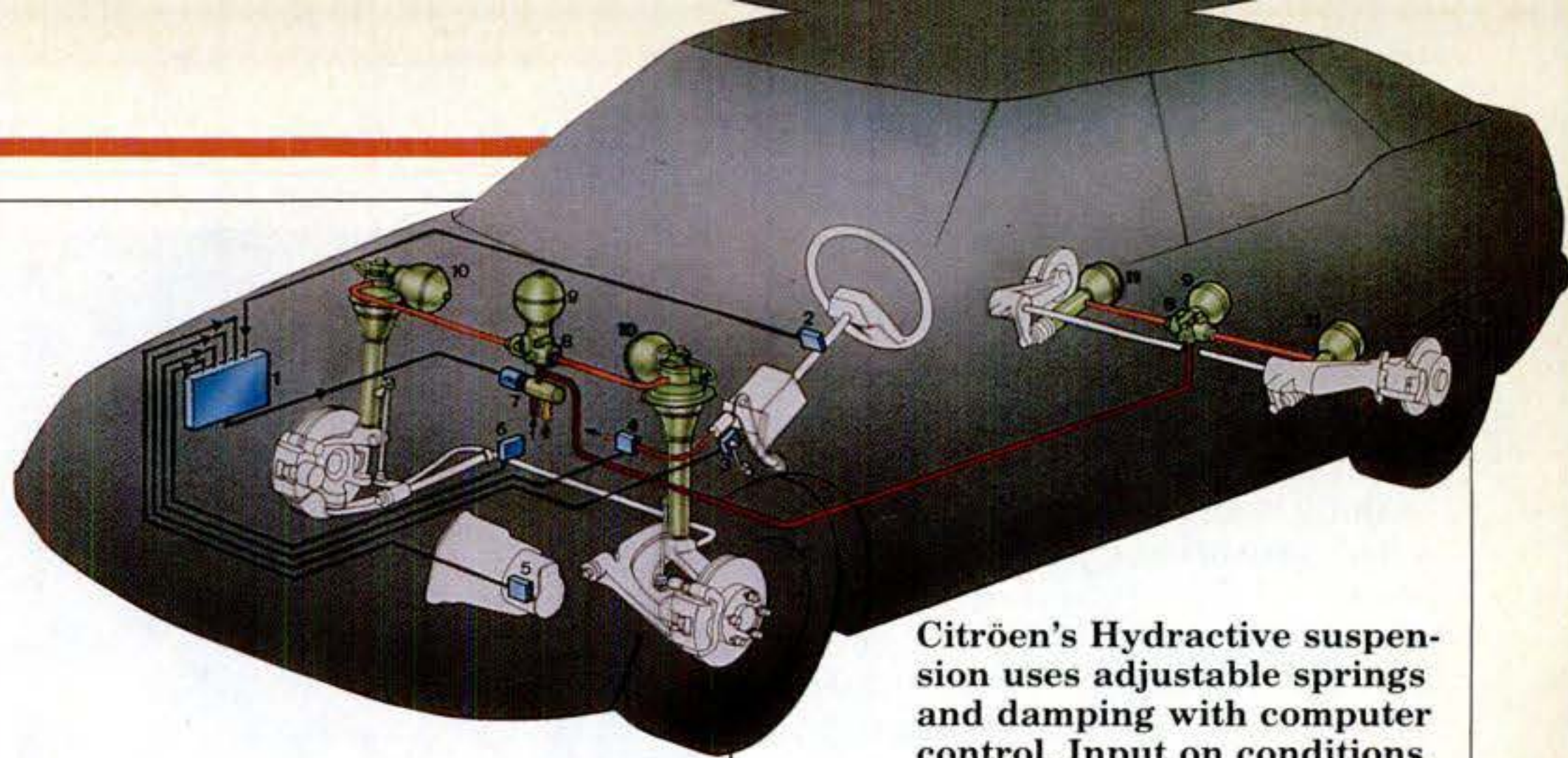
Equal length half-shafts free the Integra from unwanted torque steer. Tripod constant-velocity joints with internal splines allow shafts to expand and contract to comply with front-wheel movements.

for sale in Japan. Rather than powering the front-drive car with the 1.6-liter four-cylinder engine that employs a system of variable-valve timing, Honda engineers chose to increase the engine's displacement to 1.8 liters for the American market. Power is up by 10 percent, but more impressive is the fact that the torque curve is fatter, and 17.5 percent more torque is available compared with the old Integra engine.

The Integra retains equal-length half shafts to minimize the effects of torque steer—the tendency to turn left or right when high power is suddenly applied in a front-drive car. Integra's engineers control this by using a tripod drive-shaft joint (instead of conventional U-joints), which reduces vibration and keeps the angles of the constant-velocity joint of each axle the same. Although the Integra has more wheel travel than the Civic, which shares the platform and underpinnings, it suffers from a choppy ride over rough road surfaces. With the increased size and power of the Integra comes a more substantial sticker price, topping out at \$16,675—a far cry from its origins as an inexpensive sporty car.

Thinking suspension

The Hydractive suspension on the new Citroën XM is the latest attempt by the French car maker to produce a thinking suspension. The company's traditional gas-over-oil spring arrangement is combined with an electronic brain that automatically varies the spring rate and damping according to driving style and road conditions. It gives the best of both worlds: soft ride to isolate road shocks, and firm ride for precise handling and high-speed performance. Change-over between the two spring rates is nearly instantaneous, and determined by the control



Citroën's Hydractive suspension uses adjustable springs and damping with computer control. Input on conditions from five sensors (2 to 6) goes to the computer (1) that controls valves (7) and (8) transfers pressurized nitrogen from the master sphere (9) to front (10) and rear (11) springs.

computer based on the car's speed, steering-wheel angle, body roll, rate of accelerator pedal movement, and brake-circuit pressure. The computer compares this information with a performance map stored in its memory, and responds with the spring and damper settings best suited to the car's present path. These changes actually anticipate the dynamic response of the car, such as stiffening the suspension as the steering wheel is turned when entering a fast bend before the body has a chance to roll. All this happens without driver intervention, though a manual selector will hold the suspension in the firm setting if so desired.

New-tech wheel

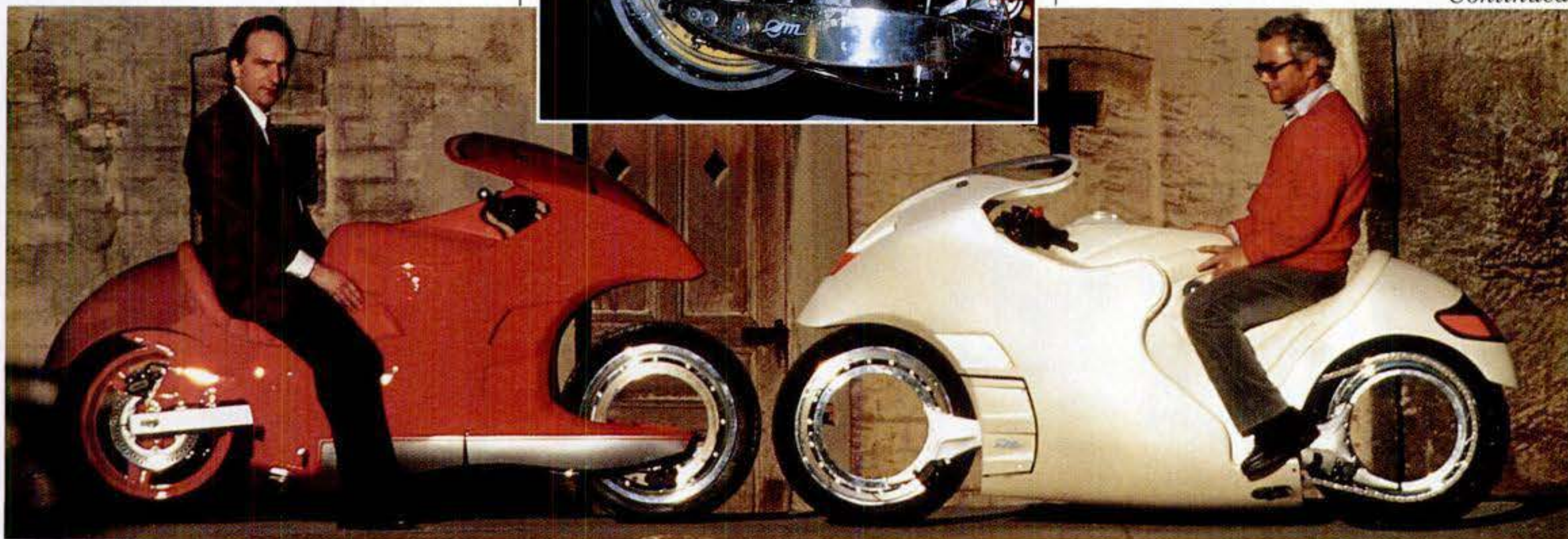
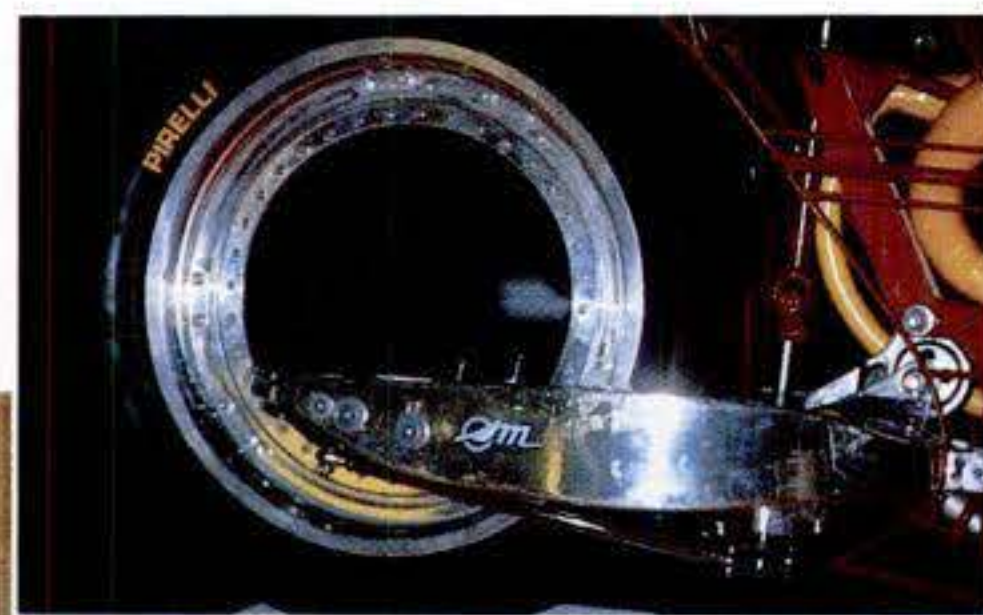
Franco Sbarro's hubless design may look more like a bizarre example of modern sculpture than a workable wheel, but the use of this revolutionary concept may lead to dramatic reductions in weight and enhanced handling. Rather than mounting a hub at the center of the wheel, the Sbarro

hubless design uses a hoop of aluminum as the rim, with a track running on the inside. The whole arrangement is supported by a lever arm whose end rides on the rim's inner circumference. This system is lighter and puts the wheel assembly's weight closer to the road, improving handling and braking, according to SM Sbarro Mottas Engineering Ltd. of Geneva, Switzerland. The first prototypes were tested on motorcycles (see photo), but Sbarro claims a version of this unique wheel will be incorporated on a sleek V12-powered high-performance supercar to be built in the near future.

BMW's new axle

The main advantage of BMW's new triple-wishbone multi-link-type rear-axle assembly is clearing enough room for the gas tank on the new 8-Series coupe. At least that's what BMW engineers claim. But the consensus of the auto journalists who drove the new setup is that it also stabilizes the car in throttle-off cornering, and is far

Continued



Motorcycles were the test bed for the Sbarro hubless wheel design (see inset above). The suspension arm rides on a track

on the inner circumference of the aluminum rim to cut weight, enhance handling, and improve brake ventilation.

more predictable at the limit than previous BMW semi-trailing-arm designs. It's a major change for BMW, with the five-link geometry effectively controlling camber change during power and braking torque.

Along with the new axle, BMW unveiled a surprising prototype of a new four-wheel-steering system. Surprising because previously BMW has derided Japanese car makers for their efforts at developing four-wheel steering.

The BMW setup steers the axle by about one degree, and only in a same-phase mode to enhance high-speed handling. The rear-wheel steering angle is applied at the inboard end of the axle pivot, and is computer-controlled to eliminate the on-center "dead" feel associated with other four-wheel-steer cars.

Hydrogen power

One reason for BMW's continuing research on alternative fuels is the growing strength of the environmental movement in West Germany, a political force that gained momentum after noticeable deterioration of trees in the Black Forest. Of concern to high-performance car makers is emphasis on excessive fuel consumption, which may lead to a speed limit being imposed on West Germany's Autobahns and tighter restrictions on automotive emissions.

This new political climate is reviving interest in alternate fuels, including hydrogen, which yields only water vapor and small amounts of nitrogen oxides as combustion byproducts. BMW has a 10-year research project testing the viability of hydrogen as an automotive fuel. A BMW 735i has been fitted with a liquid-hydrogen storage and delivery system and modified to burn the fuel.

My recent test ride in this vehicle was marred by a strong tendency for the engine to knock. Compared with gasoline, hydrogen has a low octane rating and consequently a strong tendency to detonate. The design of the fuel-delivery system must also take into account the tendency of a mixture of hydrogen and air to explode in areas other than the combustion chamber, including the intake manifold. BMW's research car injects liquid hydrogen directly into the combustion chamber after completion of air intake—a system designed to avoid potential manifold explosions.

Liquefied hydrogen is stored in a heavily insulated aluminum



While not expected for at least another year, the BMW 8-Series coupe seen below employs a new multi-link rear suspension (see detail) that is a major advance from its longstanding semi-trailing-arm design. Better control at the limit of adhesion and more room for its fuel tank are claimed as its positive points.



and fiberglass tank that holds about 25 gallons. Sensors automatically open the windows and trunk if they sniff any escaped gas.

As a fuel, the energy content of hydrogen is low, and even with a centrifugal supercharger the engine has an output 30 percent lower than the gasoline-fueled 3.5-liter six-cylinder engine standard on the car. The last problem is delivery and storage of a fuel supply. Because hydrogen liquefies at minus 423 degrees F, a self-serve gas station would be a bit tricky to engineer.

Battery Motoren Werke

A quick drive in BMW's electric-car effort is not an experience in the ultimate driving machine. The annoying

gear noise and weight of the 584-pound battery system make for a long, toiling run from 0 to 30 mph in nine seconds or so. Still, it ranks with some of the most efficient on-road electric cars produced up to this point, thanks to a sodium-sulphur battery developed by Asea Brown Boveri.

With about triple the specific energy of a conventional lead-acid battery, the sodium-sulphur-based power supply at least brings the performance within tolerable levels—a 60-mph top speed and about a 90-mile range. The drawback is that the battery has a normal operating temperature of at least 550 degrees F—more than twice the temperature of a steam boiler. If the electrolyte is allowed to solidify, it takes 4 to 10 hours to melt with an internal heating unit plugged into an outside power supply. After that, the heat generated by the battery keeps it molten unless the car is shut down for four days, then it's back to the warm-up stage.

External electrical components are powered by a normal 12-volt battery and kept charged through a converter from the 180-volt power supply. Heat is via a diesel-fuel-fired boiler circulating water through the car's heating system, and in the absence of engine vacuum, BMW developed a special mechanical brake servo. A direct-current electric motor drives the car's front wheels.

BMW's conclusion after test-

Continued



In the trunk of a BMW 735i is a heavily insulated tank that holds 25 gallons of liquefied hydrogen to power the car. Liquid hydrogen is injected into the engine to reduce accidental explosions.

Latest
Road & Track
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Highest K And X Band Sensitivity

Road & Track, Nov. 1988

BEL VECTOR 3 Radar Detector



Model 976

In *Road & Track's* recent test of currently available radar detectors, BEL VECTOR 3 rated number one in both K and X band sensitivity. Rarely is one radar detector best in both K and X bands. In fact, VECTOR 3 posted the highest K and X band sensitivity levels ever recorded! The results confirm BEL's performance advantage:

"...Vector 3 maintains a BEL tradition of excellent sensitivity, posting the highest figures in this survey for both K and X band radar." *Road & Track*, Nov '88

It's now clear. BEL technology offers unmatched performance. And with today's sophisticated radar equipment, nothing is more important than the best possible performance.

VECTOR 3's performance edge is achieved by adapting a technology used in military satellite communications. We call it Image Rejection Technology®, or IRT®. And through its use, VECTOR 3 provides a level of sensitivity unequalled by any other radar detector manufacturer—a definite advantage for detecting Instant On or Pulsed radar. And when Instant On or Pulsed radar is encountered, VECTOR 3 warns you with a separate audio alert.

But outstanding sensitivity isn't your only advantage. VECTOR 3 also detects Ka band

radar, now increasing in use throughout the U.S. and Canada. And VECTOR 3 also effectively reduces false alerts from non-police sources without any loss of sensitivity to police radar.

Laboratory Tests*

Model	Sensitivity, dBm/cm ²	
	X-band	K-band
BEL Vector 3	117.2	115.6
Audiovox RX-4	104.1	93.9
Cincinnati Microwave Escort	112.9	106.8
Cincinnati Microwave Passport	114.1	107.8
Cobra Trapshooter RD-3170	113.4	110.8
Fultron 15-0900, Snooper D-4000	109.4	108.8
Kraco KRD-16	102.7	104.7
Mascot PH222	101.5	94.6
Maxon RD-25	109.3	106.8
Radio Shack Micronta Road Patrol XK	107.6	106.0
Uniden RD9XL	113.1	108.8
Whistler Spectrum 2	115.6	110.4
Average unit	110.1	106.3

Source: *Road & Track*, Nov. 1988

*Conducted by Advanced Product Evaluation Laboratory, Inc.

BEL VECTOR 3 is the only unit in this test that also detects Ka band radar.

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A police radar signal is often buried by microwave "noise", making it invisible to ordinary superheterodyne detectors. Image Rejection Technology® however, reduces this surrounding microwave "noise" making the same police radar signal visible for early detection.



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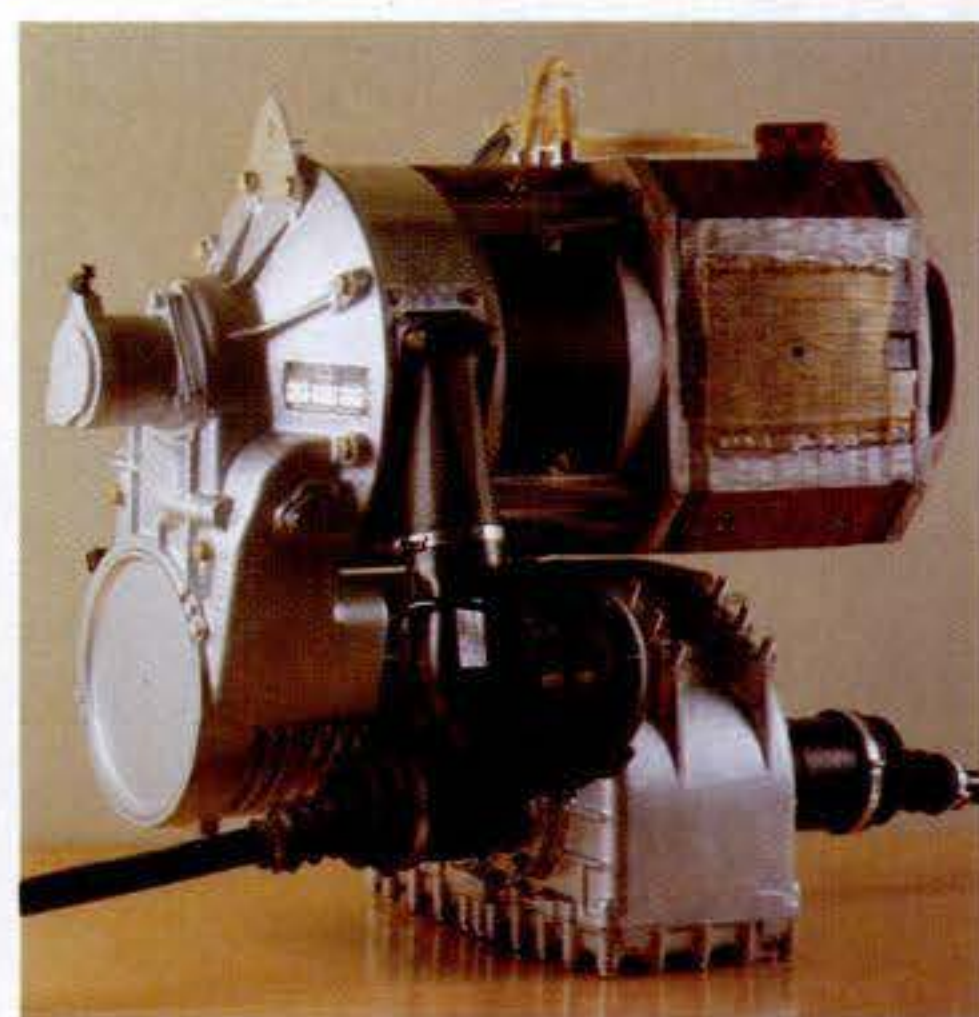
ing the research vehicle is not too hopeful for the future of such cars: "The BMW electric-drive concept cannot be a general alternative to the combustion engine." At least they tried.

Diesel redux

Volkswagen has reintroduced diesel-powered Jettas to America, thus reviving a power plant that at one time powered more than half the VW Rabbits on the road. VW executives cite rising fuel prices and a significant number

A front-drive BMW 3-Series car? Even more interesting is that it runs on electricity supplied by 90 battery cells, weighing 584 pounds.

of old-diesel owners looking for a replacement as reasons for reviving the diesel in America. While interest in passenger-car diesel engines has waned significantly in recent years, diesel installations in full-size pickup trucks have been booming, with Chrysler noting that sales of its new turbocharged diesel have been tripled from original expectations.



This all-electric drive train powers the front wheels of this modified 3-Series BMW. Top speed is 62 mph and it has a range of 90 miles.

Front-drive smokey

The fact that the police use rear-drive cars powered by V8 engines, at one time seemed almost as certain as death and taxes. Recently the state of Connecticut turned that around by purchasing turbocharged Mazda MX-6 GT models for patrol and pursuit on state highways. These front-wheel-drive cars will

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Winston

FILTERS

WINNING

augment Connecticut's aging fleet of Mustangs used for pursuing speeders. While the MX-6 GT can't compete with the Mustang GT in off-the-line acceleration, it provides better braking, better visibility, and superior all-weather traction, and has more-precise handling, according to Lt. Richard Rizzuti, who headed the car-selection project for the state police. As a bonus, the state expects to cut its fuel bill because of the car's improved fuel economy. After several laps on the state's proficiency course, the officers chosen to drive the first six sport-coupe police cars were able to trim about two seconds off the previous best time, which was turned in by a Mustang.

Alternate finish line

The 1,100-mile Methanol Marathon road rally starting in Warren, Mich., and finishing in Washington, D.C., recently ended with the University of Tennessee team taking top honors. All 15 college entries were given identical Chevrolet Corsica LT models designed to run on a mix of 85 percent methanol and 15 percent gasoline, affectionately known as M-85. The en-

gineering students had free rein as far as modifying the cars to run on M-85, which has about half the energy content of gas, but a higher octane rating. Some of them turbocharged the pushrod V6 engine, others tried upping the compression ratio from the stock 8.9:1 to 12.5:1, and at least one team tried coating the pistons with ceramic material to improve thermal efficiency. All told, the group of students achieved a fuel-economy level of 17.8 mpg for the trip, equivalent to 32.7 mpg for gasoline.

Production NS-X

Honda announced it is building a new plant to construct its NS-X sports car, a high-performance mid-engine car priced somewhere between \$50,000 and \$60,000 that is virtually all aluminum, including unit body, suspension components, and engine block ["ANF," May]. It's the most extensive use of aluminum in a production car so far, although Honda plans to build only about 5,000 cars a year at its Tochigi, Japan, facility.

The reliance on aluminum in the car means the remaining iron and steel is

minimal, although a reader took exception to my statement that you could hold the iron and steel parts of the NS-X in one hand. The probable list of ferrous-metal components includes the engine's crankshaft, four camshafts, and six connecting rods, along with brake rotors, gears, and a host of other pieces. Granted, the cumbersome nature of trying to grasp all these parts at once could make this an exercise in futility, but using weights from current production car parts, the NS-X's iron and steel parts total about 180 out of its 2,860-pound curb weight. For the record, I went to a gym, piled 180 pounds on a weight machine, and lifted it with one hand. No problem.

Van in the middle

Sources at Toyota say the company's next-generation minivan will be a mid-engine design, powered by a small single-overhead-cam four-cylinder engine mounted on its side. The van's length will be the same, but with a wheelbase stretched by two feet. The Toyota insider says the van will be well balanced and capable of pulling at least 0.80 g. **P 5**



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CONTINUITY

Electronics Newsfront

By WILLIAM J. HAWKINS

Beam me up

Robert Weisshappel, corporate vice president of Motorola's North American Cellular Subscriber Division holds what appears to be a wallet in his hand at a demonstration in Washington, D.C. Then he proceeds to unfold the tiny container like Captain Kirk's "Star Trek" communicator. "It's the world's smallest cellular telephone," he says. "You can slide it into your pocket or purse."

Called the Micro TAC Personal Cellular Telephone, the minuscule—5.5 by 2.4 by 1.6 inches—pocket phone weighs just 12.3 ounces, including its 75-minute (continuous talk time) battery. The battery lasts for 20 hours in standby when you're waiting for calls to come in.

"We were able to reduce the overall size through the design of advanced linear and digital ICs," says Weisshappel.

Using the Micro TAC is as easy as any communicator: Flip the top open, speak to answer a call. You make calls by dialing the number or by speed dialing any of the 120 user-programmable numbers stored in its memory. An LED displays the name and number of the person you've selected. There's also a call timer to show how long you've been speaking, an electronic lock to prevent unauthorized calls, and a "call" message light, which I don't understand. According to Motorola, the light comes on to show that a call has come in "while the user was away." Away from what? His shirt? Price: \$2,995.

Video viewer

Look into CAIVman (computer, audio, interactive video manipulator), and its two LCD screens display a stereoscopic interactive video show from the built-in videodisc player. Designed by Christopher Conley, the concept of a future handheld educational system for children was the winning entry of Sony's annual Design-A-Vision competition for college students majoring in industrial design.



Better than a shoe phone: Motorola's Micro TAC cellular phone has a volume of just 13.5 cubic inches and easily folds into your pocket.



Two LCD screens display 3-D scenes from CAIVman's internal videodisc. The interactive audio-video learning system is a concept of things to come.

Silence is golden

When Andrew Gabor invented the daisywheel printer in 1972, it caused a lot of noise in the industry. It was the first desktop printing system that combined high speed with high-quality printing. But it caused lots of noise in the office too. To make it work, a tiny hammer strikes each character petal 20 or more times a second. Result: a loud, annoying machine-gun sound. But now the Xerox scientist has another idea.

"The new printer produces fifty-two decibels of sound, which is fifteen decibels quieter than current designs," says Gabor. "And its frequency has been lowered by six octaves." What does all that mean?

"You don't hear it printing," says POPULAR SCIENCE Executive Editor Richard Stepler, who recently got a chance to try the system. "You only hear the operator pressing keys on the keyboard."

To quiet the mechanism and lower the pitch at which it works, Gabor had to increase the mass of the hammer that strikes the character petal. To reach the level and frequency he wanted, he calculated that a conventional hammer would have to weigh 38 pounds. "To keep the same proportions, the machine would weigh seventy-two tons," says Gabor, laughing. His alternative method is shown on next page.

When you press a key, a microprocessor determines when the correct character on the daisywheel is in striking position. When it is, the motor coil (A), attached to a connecting rod, moves vertically to rock the print bail (B), which extends across the length of the typing area. The bail pushes a connecting mechanism (C) that has a protruding print tip (D) at its end to strike the daisywheel character petal. Result: The impact force is the same as in conventional printers, but the mass has been increased to lower the frequency and sound level.

Quick looks

- The picture-in-picture (PIP) system on RCA's new ColorTrak TVs lets you freeze, pan, zoom, or replay the image displayed in the smaller TV picture.

- Magnavox offers a JBL sound system as an option to its new line of projection TVs.

Continued

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DODGE DAYTONA SHELBY. Its power over the road is absolute. 174 intercooled turbo-charged horsepower, connected to reality by a 5-speed Getrag gearbox. Its reactions to commands are supremely quick, thanks to a performance-tuned suspension and vented disc brakes at every corner. It comes with our exclusive 7 year or 70,000 mile Protection Plan* and driver air-bag restraints. And with bold, all-new ground effects styling and an aerodynamically honed shape, it is nothing short of electrifying.

THE NEW SPIRIT OF DODGE
THE PERFORMANCE DIVISION OF CHRYSLER MOTORS

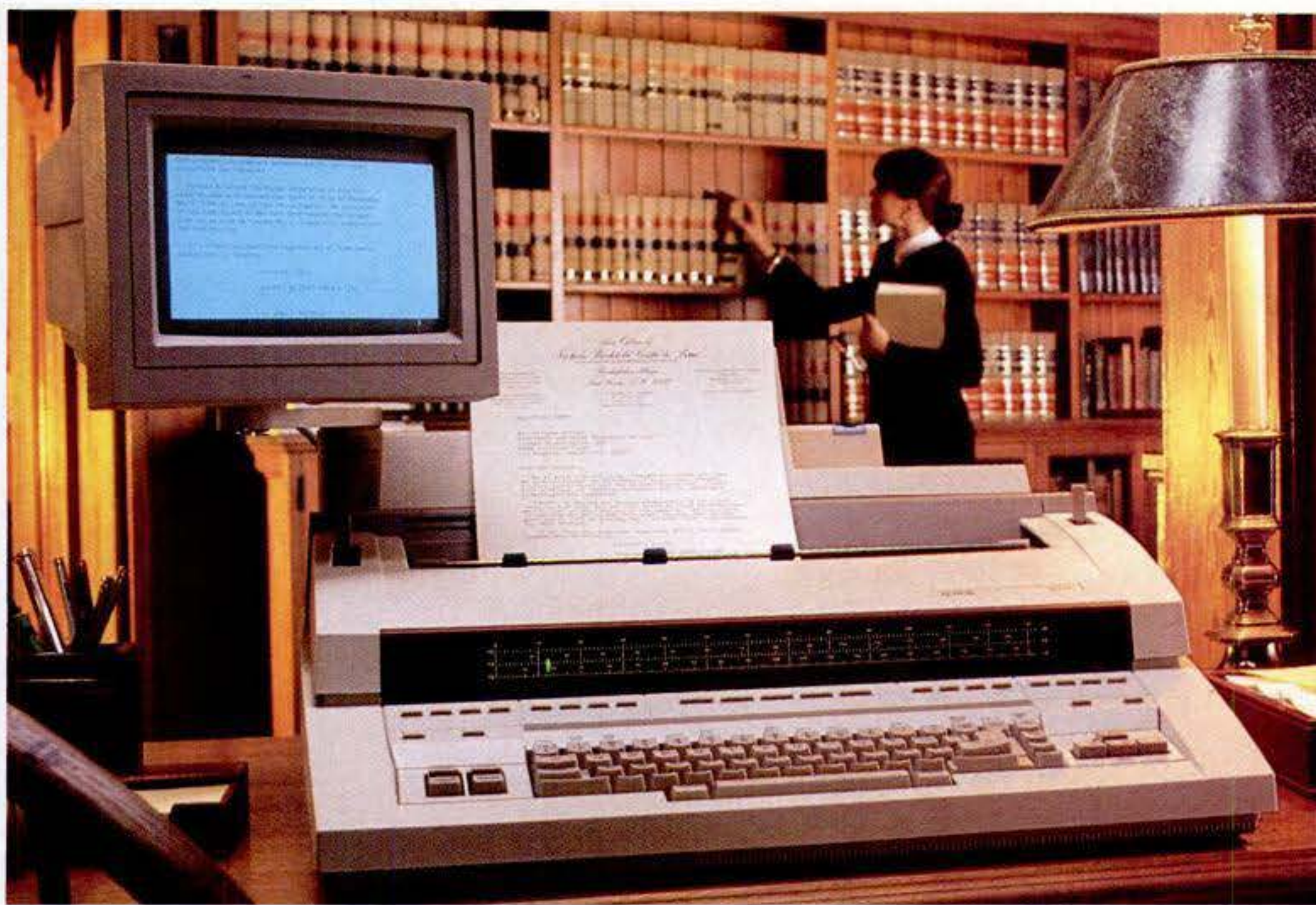


The 1989 Dodge Daytona Shelby. Designed for total performance. Body. And soul. **7/70**

BUCKLE UP FOR SAFETY.

*See this powertrain limited warranty & its restrictions at dealer.

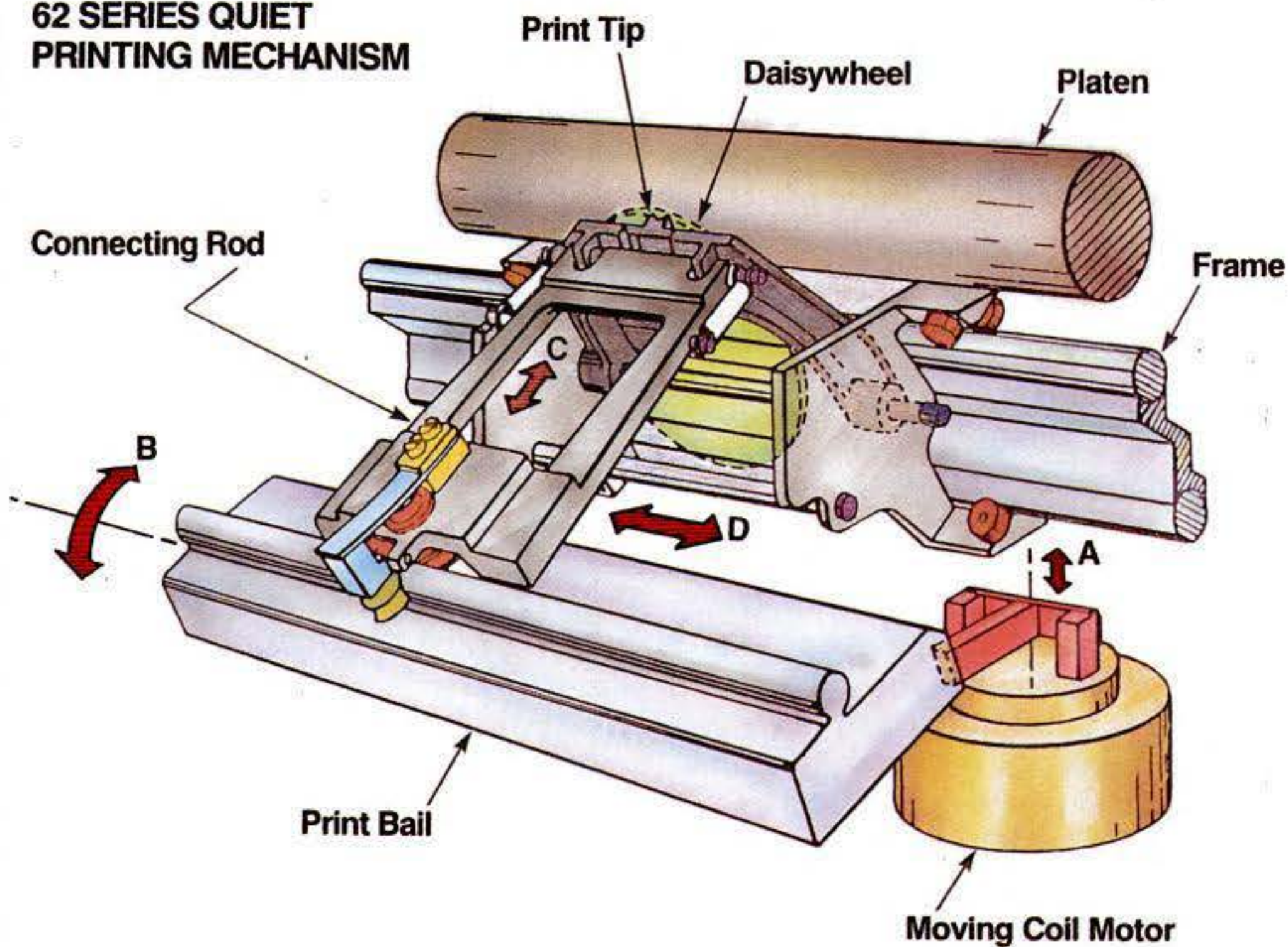
Electronics Newsfront *Continued*



Xerox uses its new quiet printer in its model 62 word-processing systems. Pri-

ces start at \$1,995. The computer-based system displays text on its 22-line screen.

62 SERIES QUIET PRINTING MECHANISM



Print bail and tip replace the conventional hammer in earlier daisywheel

printers. The greater mass lowers the volume and frequency of the sound.

- Pioneer's 45-inch projection TV delivers 650 lines of horizontal resolution. Want more? The company's 50-inch model has 720 lines. Of course only a videodisc player approaches that quality, and the company has a new one for a list price of \$600—half the price of many others. (Once discounted, it will likely be available for about \$450.) Two other models play both sides of a disc without flipping it over.

- NEC's new \$200 TurboGrafx-16 video game uses an optional CD+Graphics videodisc player for stereo sound and video special effects. The game's

16-bit microprocessor creates more-detailed graphics than its true adversary, Nintendo.

- Electrons passing through a transistor haphazardly bounce and ricochet as they flow from one end to the other. That wastes time and slows the switching speed of the device. Now AT&T has developed a hot electron transistor that lets electrons pass directly through. The increase in speed, says the company, will boost future long-distance network data exchanges from the present 1.7 billion bits per second to a trillion.

P 5

Home Newsfront

By V. Elaine Gilmore

Hot and cloudy

The 12-by-16-inch patch of plastic film between the lamp and the plant in the photo on this page is the first sample from a production line built to make a thermally active glazing material: It's transparent when cool, but turns white when it gets warm. Used in a window or greenhouse, for example, such glazing would admit solar heat when the temperature is cool, then turn white to block most of the heat when the room warms up. For use in skylights, the material can be formulated to turn white in response to sunlight as well as heat.

The glazing is called Cloud Gel, and if you read the March 1984 issue of *POPULAR SCIENCE*, you may recall seeing a photo of a hand-made prototype. Cloud Gel's inventor, Day Chahroudi, also gets much of the credit for inventing Heat Mirror, the first low-emissivity glazing [April '82, March '86].

The path from prototype to product for Cloud Gel was longer and bumpier than Chahroudi expected. But now his company, Suntek, Inc., in Albuquerque, N.M., has its production machinery cranked up and undergoing the critical fine-tuning stage before samples can be manufactured and put out for testing.

Cloud Gel is a polymer-water solution (specifics are proprietary) sandwiched between plastic films. When the solution is cool, the polymers are elongated; their diameters are much smaller than wavelengths of solar energy, so the sun passes readily through. As the solution warms, the polymers curl up, and the globs become larger than solar wavelengths. So 80 percent of the solar radiation is reflected.

The temperature at which Cloud Gel changes from clear to white can be adjusted in the manufacturing, but would typically be in the 75 to 85 degree F range, depending on use. Its first applications will probably be in greenhouses, translucent building panels, and skylights, according to Chahroudi.

There are other contenders in the "smart" or switchable glazing field. You probably know about electrochromic



Cloud Gel, a polymer-water solution sandwiched between plastic skins, is transparent when cool, but turns white as it warms. Used as glazing it would act as a solar-energy valve, transmitting or reflecting solar heat and light to keep a building comfortable under varying climatic conditions.

glazing [Dec. '87] and glazing based on liquid crystals [Aug. '88]. *POPULAR SCIENCE* will report on another, called suspended-particle display, in a future issue. All of these technologies require an applied voltage to trigger the transition. Consequently, Chahroudi is convinced that Cloud Gel will be much cheaper to produce.

Looks like the race is on for a smart window.

The energy-efficient mortgage

How much house can you afford?

If the one you're buying has a delicate appetite for energy, you may be able to take out a larger mortgage—and thus afford more house. The Federal National Mortgage Association (Fannie Mae) and the Federal Home Loan Mortgage Corp. (Freddie Mac)—agencies that buy mortgages from banks and, thus, set many of the guidelines—offer a program called the "Energy-Efficient Mortgage."

Normally, both Freddie Mac and

Fannie Mae specify that when principal, interest, taxes, and insurance are considered, payments should amount to no more than 28 percent of the borrower's gross monthly income. With an Energy-Efficient Mortgage, however, that maximum can go up to 30 percent. "A borrower's ability to make monthly payments is enhanced when the home is energy-efficient and a borrower is required to devote less of his income to utility expenses," explain the Freddie Mac guidelines.

To qualify for the program, the home buyer must document the home's efficiency. That can be done by a qualified appraiser or by an energy-audit service. Or the mortgage banker can accept categorically those homes that comply with recognized energy-performance standards.

Home-energy stickers?

There are several moves afoot to do for houses what the Environmental Protection Agency's mileage ratings did for cars: devise a uniform system for pre-

dicting their energy performance. The Thermal Performance Guidelines, developed by the National Association of Home Builders' National Research Center, is one such effort. More than 40 of the current voluntary home-efficiency programs in the United States are based on those guidelines, according to Bion Howard, the senior energy analyst at the National Research Center.

In addition, a not-for-profit corporation called Energy Rated Homes, based in Little Rock, Ark., is setting up local energy-rating programs around the country. These are run by builders, lenders, appraisers, realty agents, and utilities. (Both of these programs are among the energy-performance standards accepted by Fannie Mae and Freddie Mac for Energy-Efficient Mortgages, by the way.)

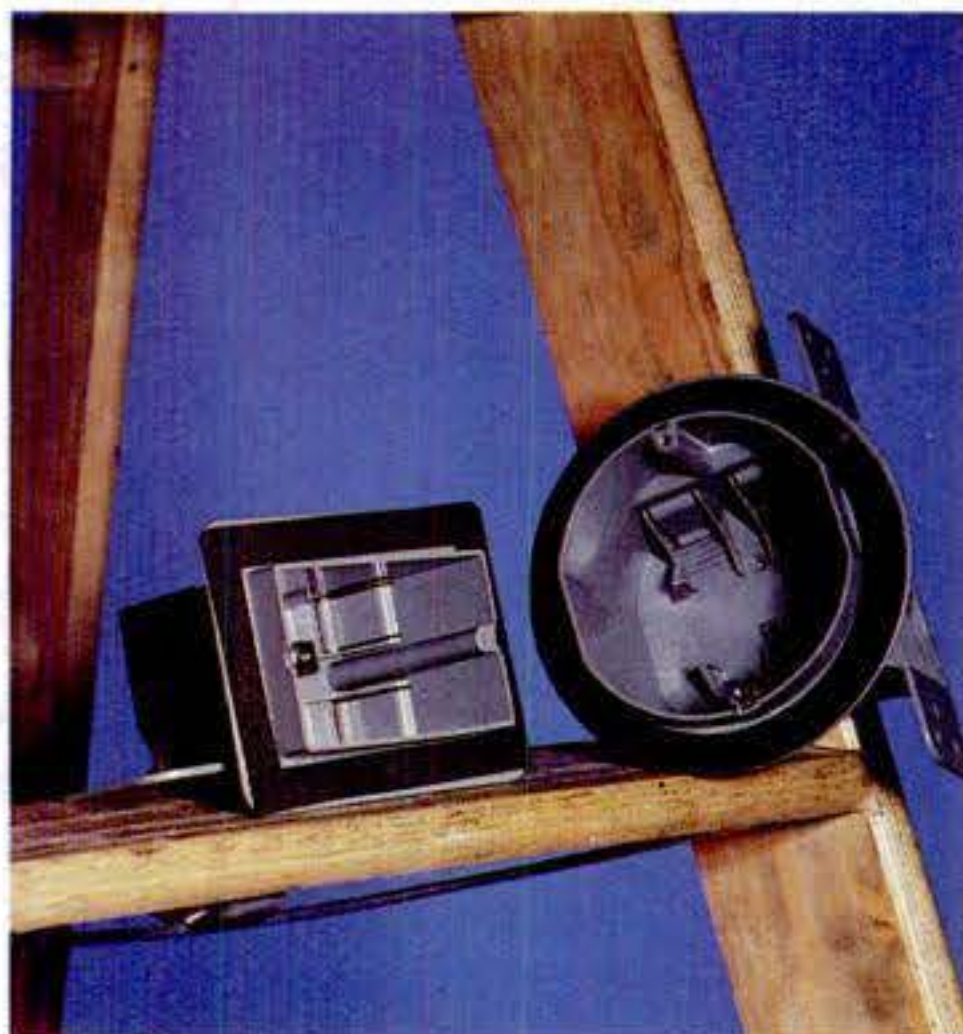
One day, when you're out house hunting, you may find an energy-rating sticker on every door, or maybe pasted on a mechanical-room wall, out of public view. And no doubt you'll see some variation on the phrase: "Your actual Btu usage may differ..."

Better boxes

Electrical outlet and fixture boxes are pretty effective energy losers considering their small size. They contain several sizable holes for air infiltration, and they're made of metal, which transfers heat readily.

Now Nu-Tek Plastics, in Delta, British Columbia, has introduced a line of airtight (or nearly so) electric boxes. The boxes are made of a General Electric engineering plastic called Noryl, so they do not conduct heat as readily as metal boxes.

You can see the foam gaskets that seal around the front flange of the boxes in the photo. More foam covers the back of the hinged slots where the wire is inserted. "The electrician just slits the foam at the cable entry point," says Wayne Harington, president of Nu-Tek. "Then all that is needed is a dab of caulk to seal the unit."



Air-tight electric boxes have only four holes for wires and mounting screws, which you seal with caulk after installation. And they're plastic, which conducts heat less readily than metal.

Wall and ceiling boxes in several configurations are available from Nu-Tek Plastics (#2-4703 51st St., Delta, B.C. Canada). They are not UL approved, but they are approved by the Canadian Standards Association. And many states, plus some U.S. cities, accept CSA certification (check with your local authorities).

Info mart

- If you don't know a cripple from a batter board—and you'd like to—you'll enjoy the American Plywood Association's primer on the wood-frame house. It's called "House Building Basics", and it's yours for \$2.95—from the American Plywood Assn., Box 11700, Tacoma, Wash. 98411.

- A brochure from the American Gas

Association called "Energy-Efficient Gas Furnaces and Appliances" explains such fundamentals as how to read the yellow "energy-guide" labels on furnaces and appliances and defines enough terms to let you compete—jargon for jargon—with an appliance salesman. The brochure is free from the American Gas Assn., Public Information Dept., 1515 Wilson Blvd., Arlington, Va. 22209.

- Another freebie, this from the Department of Energy's Conservation

and Renewable Energy Inquiry and Referral Service (CAREIRS), could be useful if you're planning some fall planting. It's called "Landscaping for Energy-Efficient Homes." Two phrases from the introduction should pique your interest: 1) "A well-placed windbreak of evergreens can reduce your heating bill by 20 percent." 2) "One tree absorbs the same amount of Btu in a given day as five air conditioners running for 20 hours." (CAREIRS, Box 8900, Silver Spring, Md. 20907). **PS**



Since radar displays only one number, the operator has the responsibility to decide which vehicle is being clocked.

Why radar makes mistakes. How to protect yourself.

It's hard to believe, but traffic radar does not identify which vehicle is responsible for the speed displayed. It shows only a speed number. The radar operator must decide who to blame.

How radar works

The radar gun is aimed at traffic and it transmits a beam of invisible radar waves. Moving objects reflect these waves back to the radar gun. Using the Doppler principle, the radar calculates speed from the reflected waves. But there's a problem.

The best guess

Remember, these reflections are invisible. And truck reflections can be ten times stronger than car reflections. How can the operator know for sure which vehicle is responsible for the number?

The truth is, in many cases he can't be sure. The result? You can be ticketed for somebody else's reflection.

The only way to defend yourself against these wrongful tickets is to know when radar is operating near you.



Self Defense

We specialize in radar warning. Escort and Passport have a unique warning system that tells you radar strength—with both a variable-rate beeper and a visual

meter. You'll know when the radar unit is near enough to have you under surveillance.

Car and Driver, *Popular Mechanics* and *Roundel* magazines have each tested radar detectors. And each gave us their highest ratings. Call toll-free and we'll send reprints of the complete tests.

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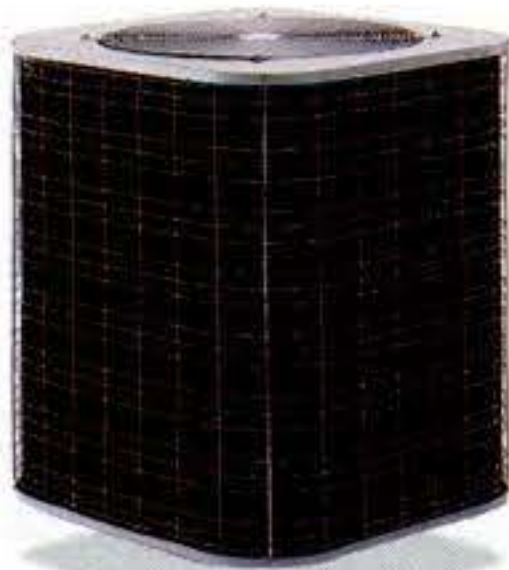
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PS

Looking Back...

Sampling a century of POPULAR SCIENCE

100 YEARS AGO AUGUST 1889

"It has generally been accepted by most physicists that electricity is a phenomenon resulting from oscillations of the luminiferous ether. However, with the exception of a few experiments instigated by Maxwell's 'electromagnetic theory of light,' no verifications of this hypothesis had been made until late last year, when Prof. [Heinrich Rudolf] Hertz, of Carlsruhe, Germany, commenced a series of experiments on the interference of electrical waves.

"In Hertz's experiment, the wavelength of the conductor was 2.8 me-

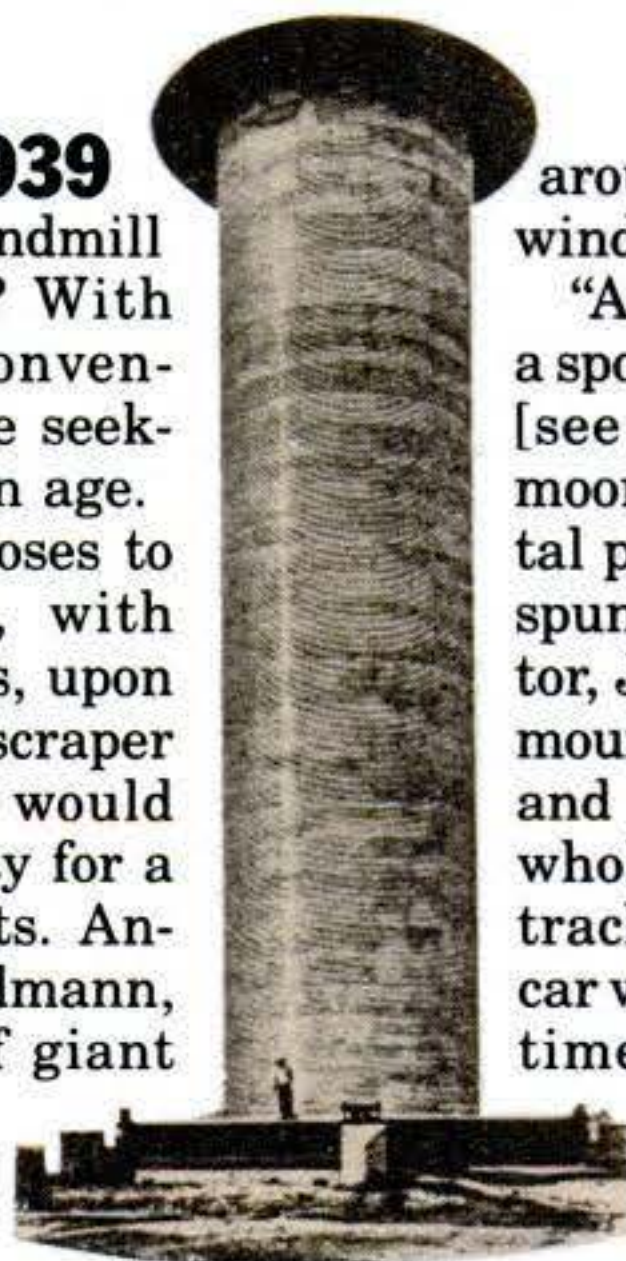
ters. From this value, he gets the velocity of propagation of electrical disturbances as 200,000 kilometers per second. This is truly wonderful.

"It would seem that Hertz's wavelengths are of an entirely different order from what they should be. How can electrical wavelengths of one meter be in any way associated with light waves of less than one billionth of a millimeter? Still, should the velocity of propagation of electrical waves be much greater than has been supposed, then with these large wavelengths the times of oscillation could be of the same order as those of light."

50 YEARS AGO AUGUST 1939

"Is the windmill coming back? With strange, unconventional types, inventors are seeking to adapt it to a modern age.

"Hermann Honnef proposes to mount 500-foot wheels, with spokes that serve as vanes, upon high towers. A single 'skyscraper windmill,' he estimates, would generate enough electricity for a city of 100,000 inhabitants. Another designer, Peter Bendmann, offers plans for a pair of giant windmills, connected at right angles to each other and arranged to move



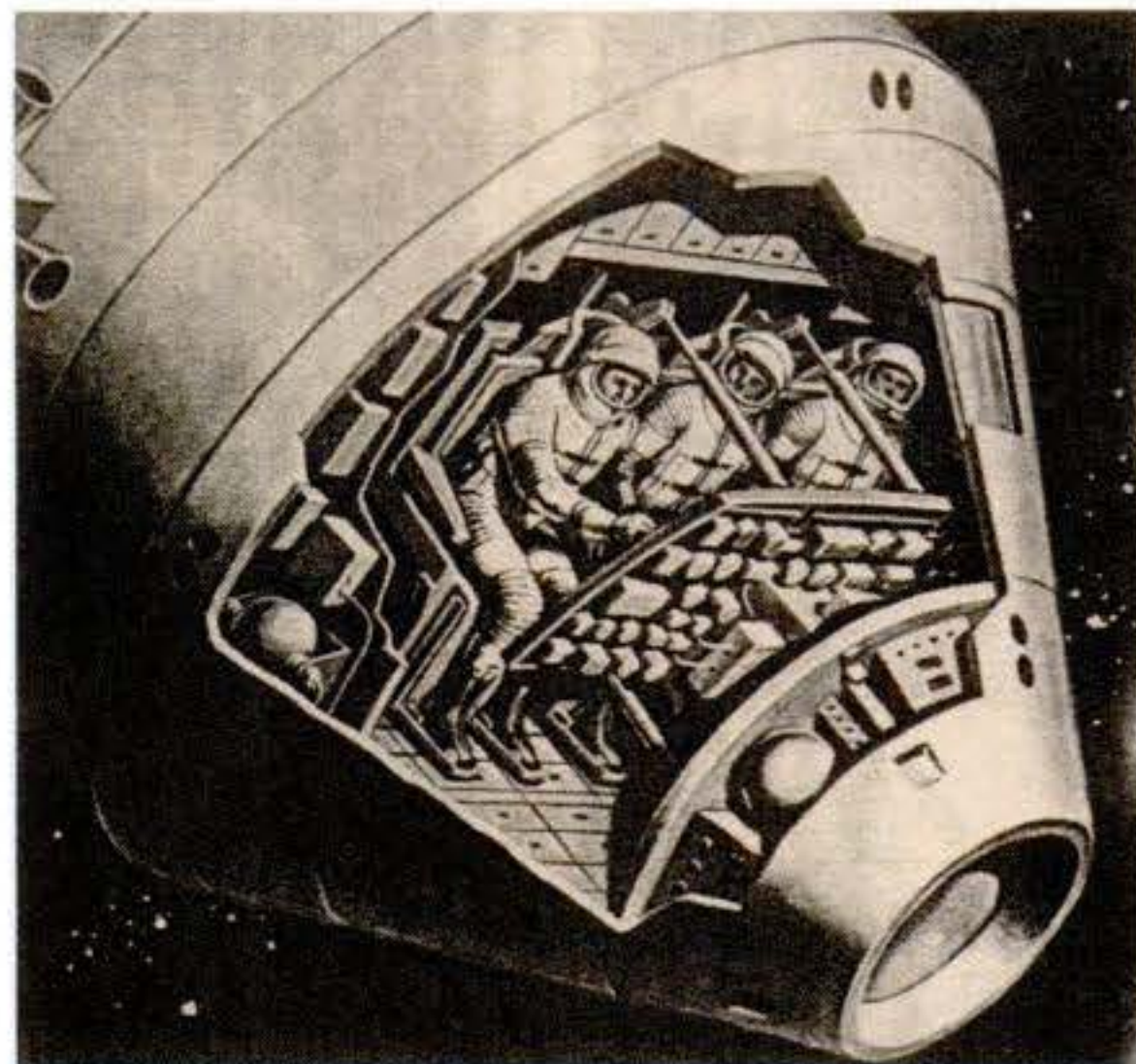
around a track so as to obtain wind power from any direction.

"At Burlington, N.J., recently, a spool-shaped rotor 90 feet high [see drawing] strained at its moorings with a 10-ton horizontal pull, when an electric motor spun it in the wind. The inventor, Julius D. Madaras, plans to mount 20 such rotors on flat cars, and make the wind propel the whole train around a circular track. Dynamos geared to the car wheels would generate many times the amount of power needed to turn the rotors, and the surplus power would be marketed."

25 YEARS AGO AUGUST 1964

"What will that first trip be like when—soon—brave men soar into the skies to conquer the Moon? Here is a preview of that great adventure.

"Atop their vast and audibly seething assembly, three men lie breathing quickly in concentration as Earth and rocket begin to cast off lines. In the last second 100 switches clatter, fires are kindled, valves open, flames belch and cough smokily. Long, slow vibrations run upward through the rocket to jostle the crew, then begin smoothing away as the launch pad's hold-down clamps fall. The Saturn poises, struggling against Earth's gravity and an atmosphere cling-



ing like glue to its sides. It rises in a thunderous stroke to stage-one burn-out at 150 seconds and 36 miles."

Why it takes legwork to flatten your stomach

You can't reduce stomach fat by exercising abdominal muscles alone.

Research has shown that exercises that work only the abdominal region are not effective. They simply don't involve enough muscle mass to burn the calories necessary to trim fat. Instead of flattening, they merely strengthen underlying muscles, providing no reduction in girth, fat-folds, or total body fat percentage.

The exclusive NordicTrack® total-body aerobic exerciser is the most effective way to flatten your stomach.

The total-body motion involves *all* major body muscles. Which means you burn more body fat in less time than with any other in-home exercise machine. And while you're at it, you're toning and defining those muscle groups, as well. So you feel as good as you look.

Patented Flywheel
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Non-Jarring Motion
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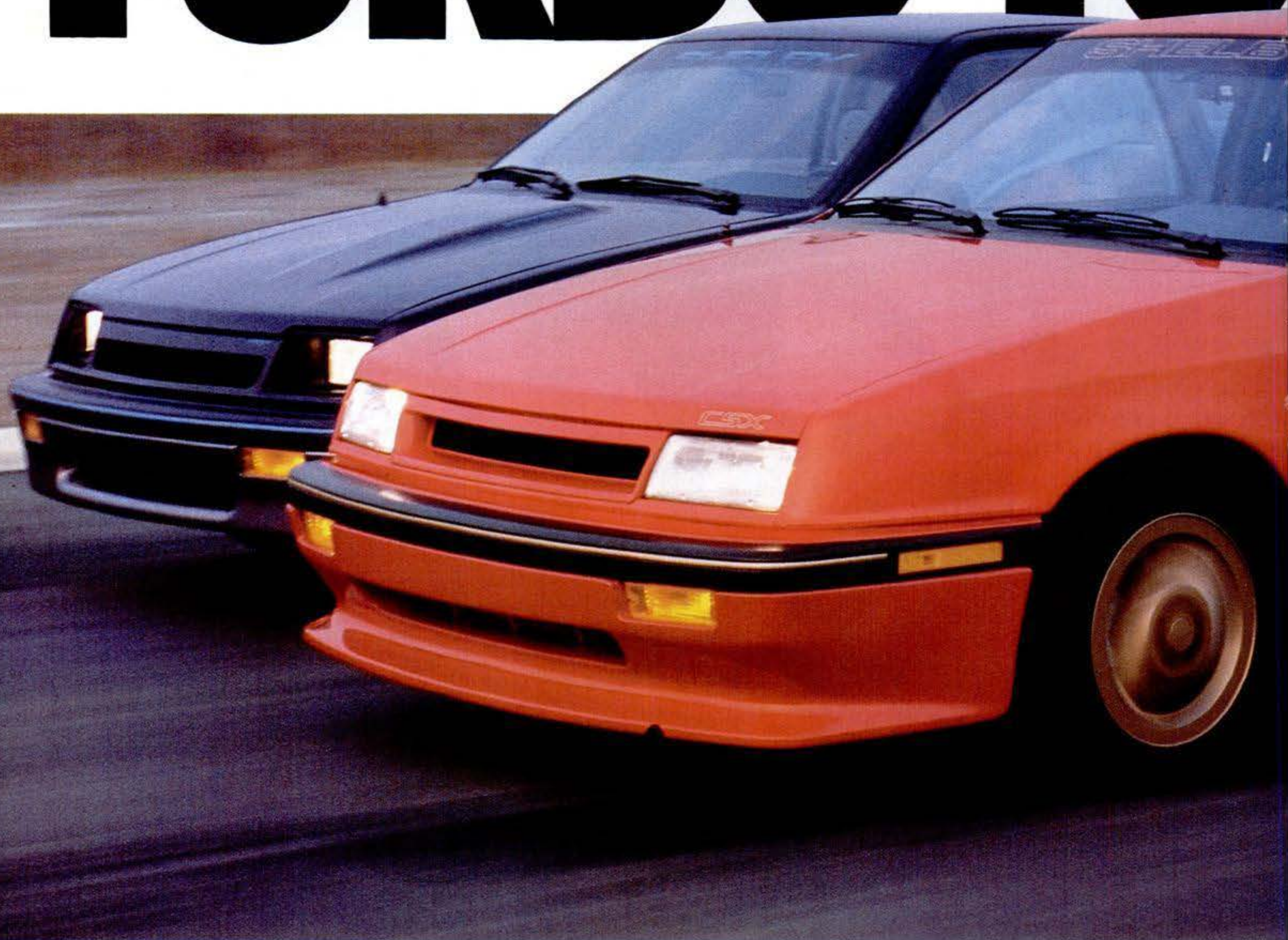
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TURBO TO



The 1989 Shelby CSX Turbo IV with variable-vane turbocharger (red car on right) out-accelerates a similar standard turbo-equipped Shelby CSX (blue car on left). Both are rated at 175 hp, but the variable-nozzle turbocharger responds to the throttle faster, giving it an edge in acceleration. Right: The engine bay of the Shelby CSX with the Garrett Automotive T25 turbocharger differs only slightly from the older Shelby CSX.

By **DAN McCOSH**
Detroit Editor

There are some dark secrets in the car tester's closet, and one of them is that testing fast isn't always the same as going fast. It's not uncommon for a car to clock single-digit 0-to-60-mph times without impressing the seat of your pants, particularly when the car is turbocharged, and the standing start at the test track is preceded by revving the engine to the redline and dumping the clutch.

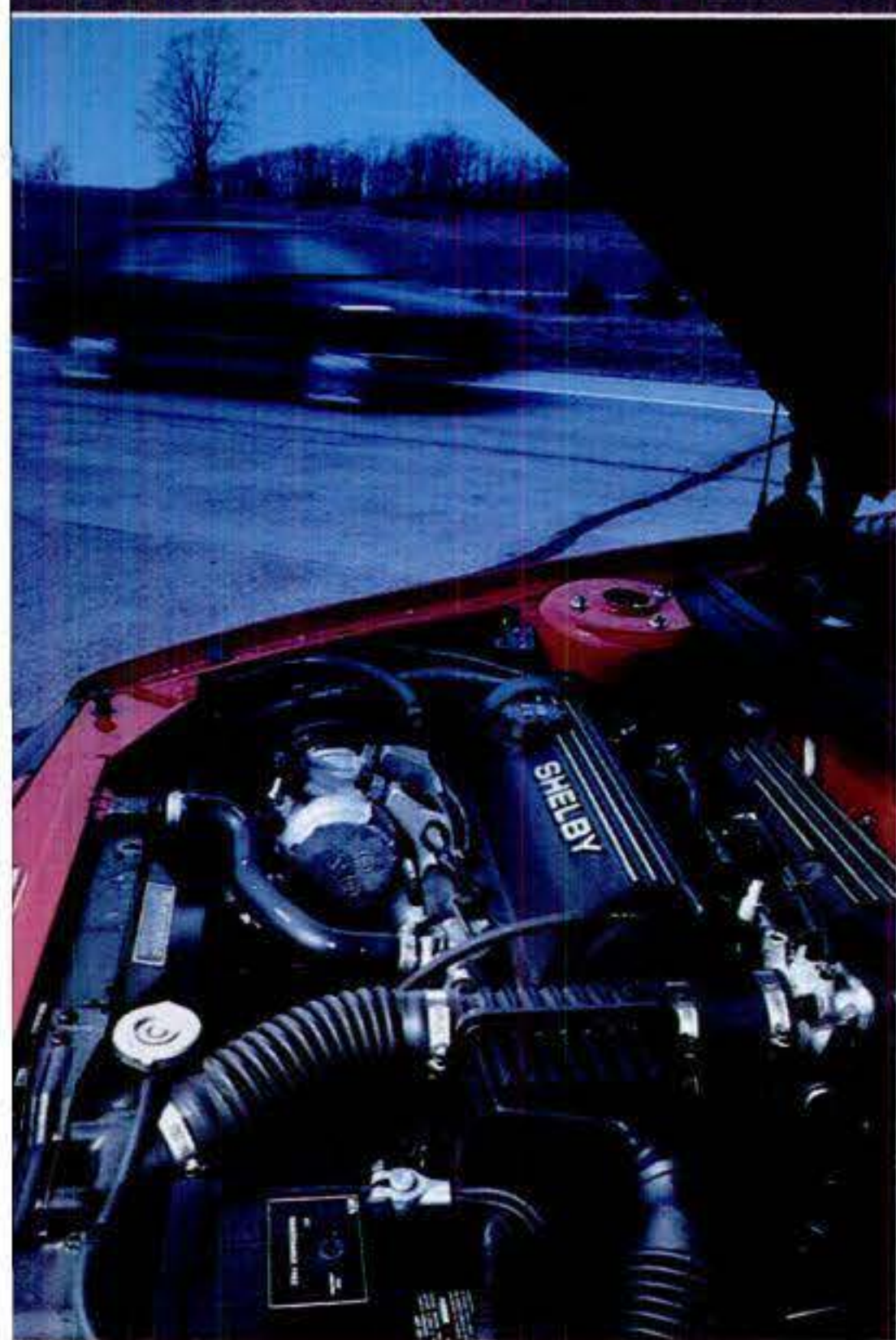
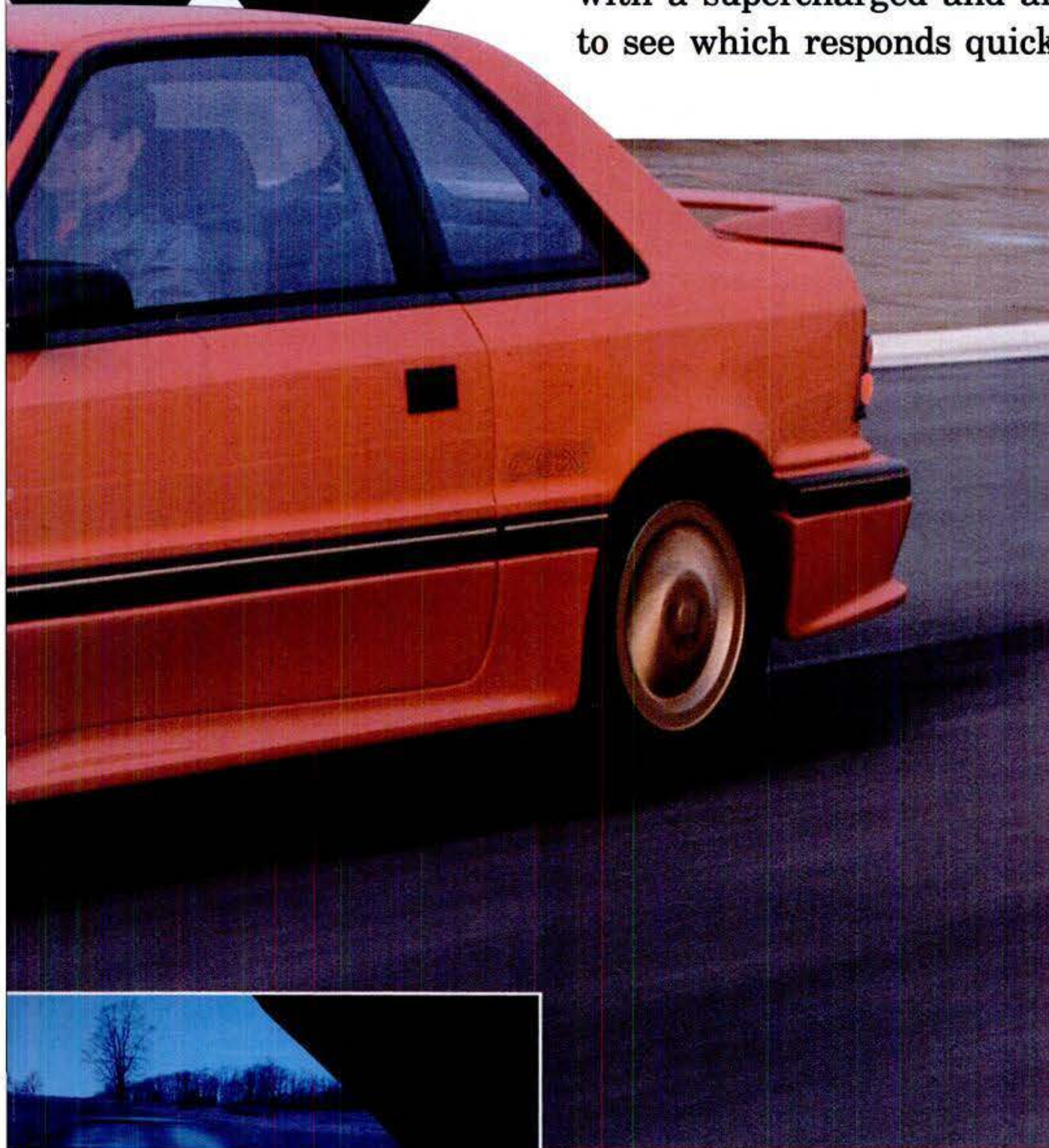
The real world isn't always so controlled. Say you're crawling up a grade behind a wall full of travel stickers on the back of some guy's Airstream

trailer, and you pull out to pass. That's when turbo lag rears its ugly head.

A stab at the gas pedal is rewarded with a long, slow buildup as the turbo goes into its act. Boost painstakingly rises, and finally the car gets going with a rush. But by that time you've already passed the guy and his trailer, and now you're in blastoff mode just when you want to get back into your lane.

The answer to the sluggish response of some high-horsepower turbocharged cars is promised by the development of variable-nozzle turbochargers (VNT) [Cover story, May '88]. These innovative new devices use a ring of vanes around the turbine wheel to precisely direct the exhaust gas stream for maximum efficiency.

GO



To be most effective, a turbocharger must be both small for quick response and large for high-revving efficiency. The variable-nozzle turbo fitted to the 1989 Shelby CSX adjusts its internal geometry automatically, making it two turbos in one. **POPULAR SCIENCE** tests this innovative turbo along with a supercharged and an atmospheric-pressure engine to see which responds quickest to the gas pedal.

IV intercooled turbocharging system and an older sister, a late-1987 Shelby CSX equipped with most of the Turbo II hardware. Both cars are powered by Chrysler's 2.2-liter four-cylinder engine and are rated at an identical 175 horsepower, although the newer Shelby CSX develops more torque. To see where turbocharging fits into the larger engine picture, we also tested a 1989 Ford Thunderbird Super Coupe with a 3.8-liter V6 engine boosted by a belt-driven Roots-type supercharger [Cover story, Jan. '87]. And as a base line, we looked at the throttle response of a 1990 Plymouth Laser equipped with a 16-valve two-liter four-cylinder engine that operates at atmospheric pressure.

Range of power and weight

The group of four cars included several combinations of weight and power. The Thunderbird Super Coupe is substantially heavier than either Shelby CSX and, despite its 210-hp output, has a power-to-weight ratio of 18.6 pounds per horsepower, slightly worse than the '89 Shelby's 16.1 lb./hp. The '87 Shelby CSX weighs 100 pounds lighter than its newer Shelby cousin and has an advantageous 15.3 lb./hp ratio. The weight difference is accounted for by the '89 CSX's heavy-duty suspension, extra sound-deadening material, and heavier ground-effects skirts. The Laser's weight is virtually the same as the older Shelby CSX, but with 135 hp available, it has a power-to-weight ratio of 19.8 lb./hp. The mismatch would make raw-acceleration comparisons more or less predictable, but we were more interested in testing how quickly the cars responded to a stab at the gas pedal, not which one pulled ahead faster from a stoplight.

We quickly discovered that testing a car's responsiveness is considerably trickier than testing its raw acceleration to 60 mph. To begin with, while the differences in horsepower-to-weight ratios indicated we could expect a range of acceleration times, all three boosted cars were within 0.9 second of each

Continued

PHOTOS BY JOHN B. CARNETT

By speeding up the exhaust flow at medium engine speeds, the turbocharger's turbine wheel can get to its optimum speed quickly and improve throttle response. This new turbo technology made its debut this spring on a limited-volume Shelby CSX, based on the Dodge Shadow sports coupe. And Chrysler plans to add this innovative turbocharger to other models in the 1990 model year.

Turbo-charged debate

Is VNT the answer to turbo lag? It's the type of question that leads to endless debate without much substance. We decided to try for a more definitive answer.

To start with, we gathered together a 1989 Shelby CSX with the VNT Turbo

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Turbo to go *Continued*

other at reaching 60 mph. The supercharged Thunderbird blasted to 60 mph first, in 7.8 seconds, just 0.3 second ahead of the VNT-equipped Shelby CSX. The standard turbo-equipped Shelby got to 60 mph in 8.7 seconds, and the lower-powered Laser took 10.3 seconds.

Responsiveness testing

But we wanted to test for response, and 0-to-60-mph times can be misleading. A fast run at the drag strip can consist of a slow start and a quick finish or a quick blastoff followed by a letdown. We wanted to profile the car's acceleration, because contests like this are won or lost in the blink of an eye.

In search of a better measure of throttle response, we decided the determining factor should be how quickly each car reached its maximum acceleration, even if the peak differed from car to car. Even more significant was each car's pattern of acceleration. A quick-responding car should show a steeper climb to its maximum acceleration, while a lagging car would be likely to start at a lower plateau, then rise slowly.

The instrument to do this is the g.Analyst, developed by Valentine Research (see box, G whiz!). The g.Analyst measures acceleration and records it in one-tenth of a second intervals. This device gives acceleration readings at any point in time. Our hope was that the g.Analyst would give us a way to actually measure how long it takes to get to peak acceleration—rather than relying on gut feelings. In this way we could quantify and compare acceleration lag.

Track tests aside, however, the basic principles and engineering behind the various systems of horsepower enhancement seemed to give one an edge over the others.

Turbo theory

Slow throttle response has plagued turbochargers since they began showing up in significant numbers in the United States in the 1970s after gaining popularity in Europe. They were popular because they seemed to promise something for everybody in the midst of an energy crisis. But there was a major drawback: less than crisp response.

The idea involves designing a small displacement engine that can become a tiger on demand. When you don't need extra power, the engine is a fuel sipper. But step hard on the accelerator pedal, and the boost comes on. Extra air is forced into the engine, so it can burn more fuel and produce greater power output. What's more, the compressor that jams the extra air in is

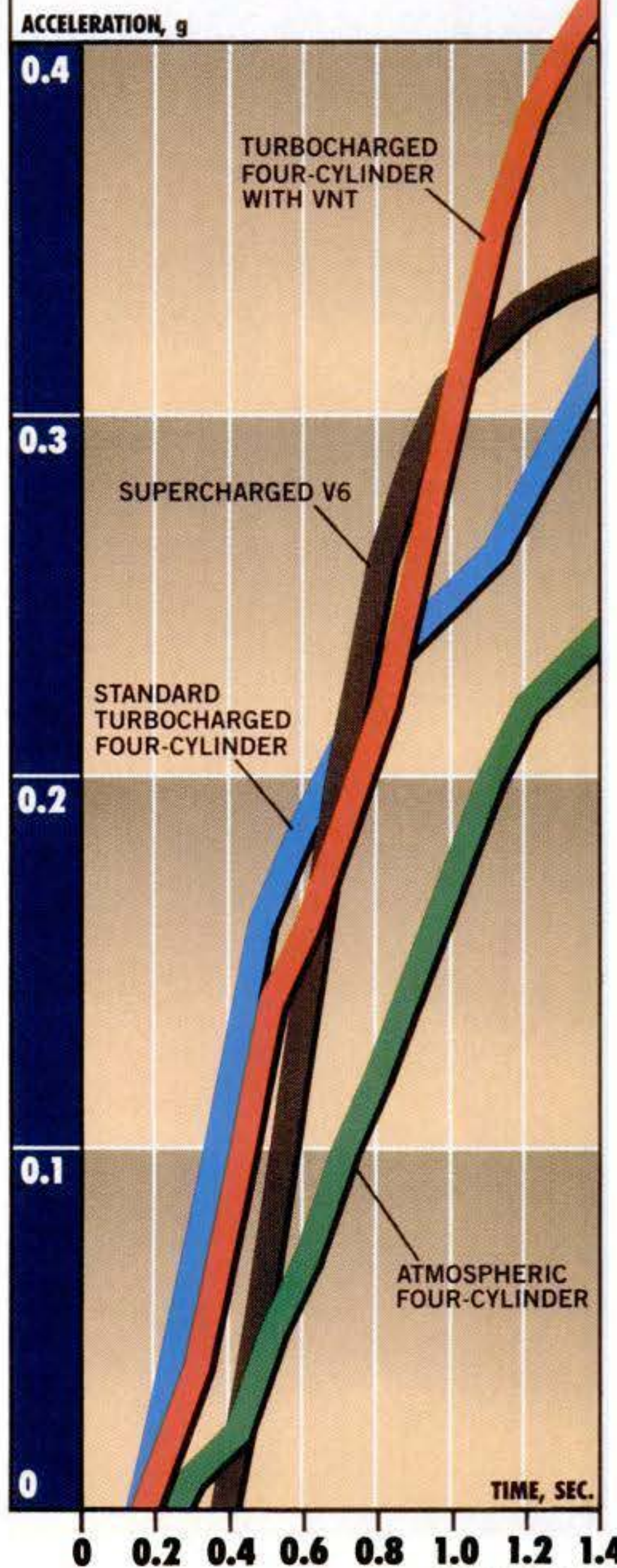
driven by the heat of the exhaust—almost a free ride, because this waste heat would otherwise be dumped into the atmosphere.

More than any other auto manufacturer, Chrysler Corp. embraced turbocharging, not only for performance cars, but eventually for sedans and minivans. Chrysler's limited supply of large-displacement engines encouraged attempts to power a wide variety of models with derivatives of its basic 2.2-liter four-cylinder engine that delivered 92 hp in atmospheric-pressure form. Turbocharging brought the engine's power up to the level of competitive V6s, but at the cost of throttle response.

Chrysler engineers were quick to realize turbocharging's limitations. Early models used a relatively large Garrett T3 turbocharger that was originally designed for small trucks. The weight

Continued

SECOND GEAR THROTTLE RESPONSE



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TOYOTA TRUCKS

The Competition's Saying A Lot About Their Engines.
Here's What Motor Trend Says:

**“The V6-powered Toyota SR5 Ran Away
From Every Other Truck In The Field.”**



Which isn't a surprise, considering Toyota's three-liter, electronically fuel-injected V6 is the most advanced compact truck engine available. Meaning it squeezes out more horsepower per liter than any engine in its class. All together, 150 wild stallions.

Just one reason Motor Trend named Toyota “Truck of the Year.” Which leaves the competition no alternative but to talk among themselves. So if having the most advanced compact truck engine is your objective, take it from an objective source—pick up a winner.

Call 1-800-GO-TOYOTA for more information and nearest dealer location.

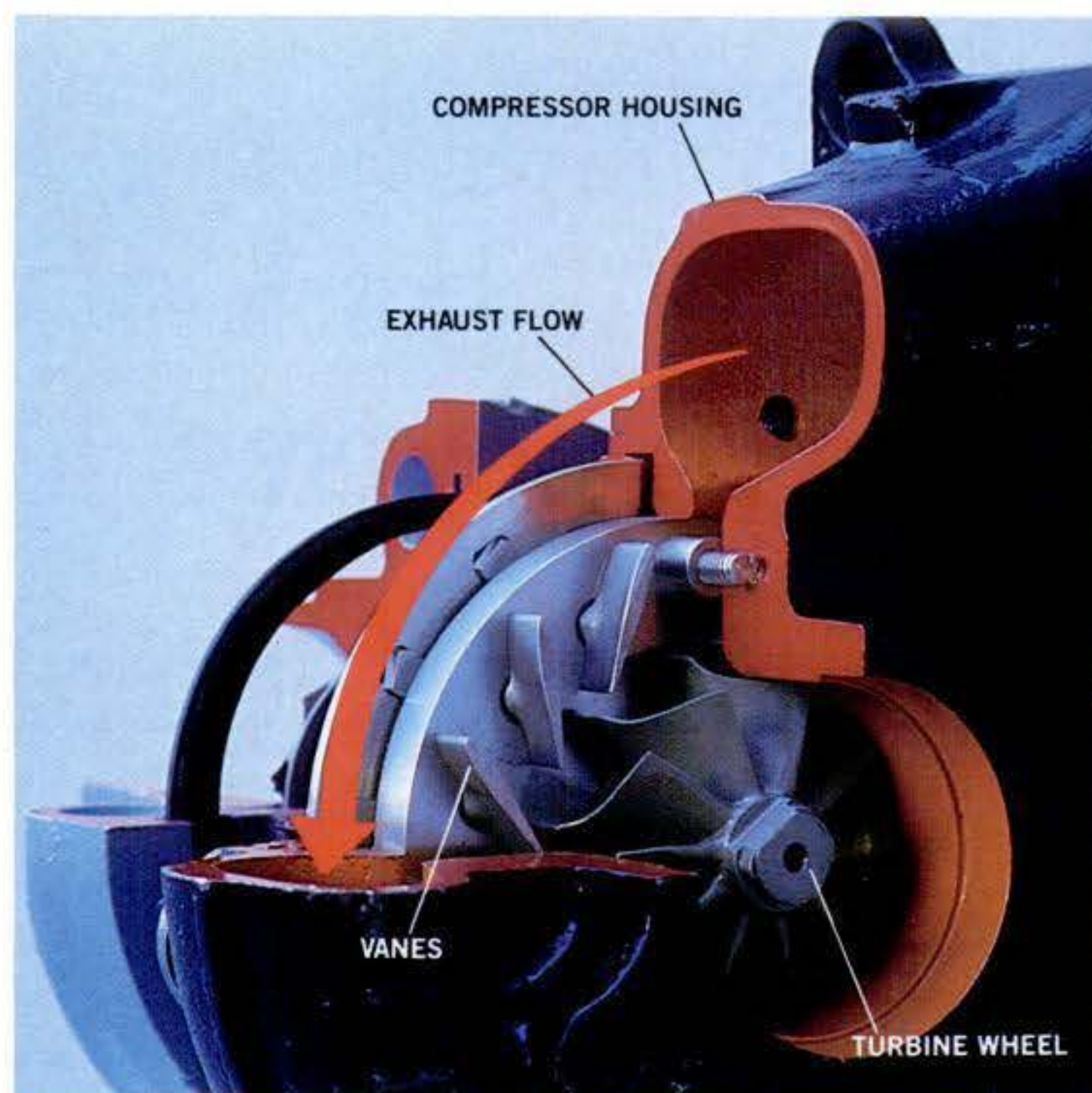
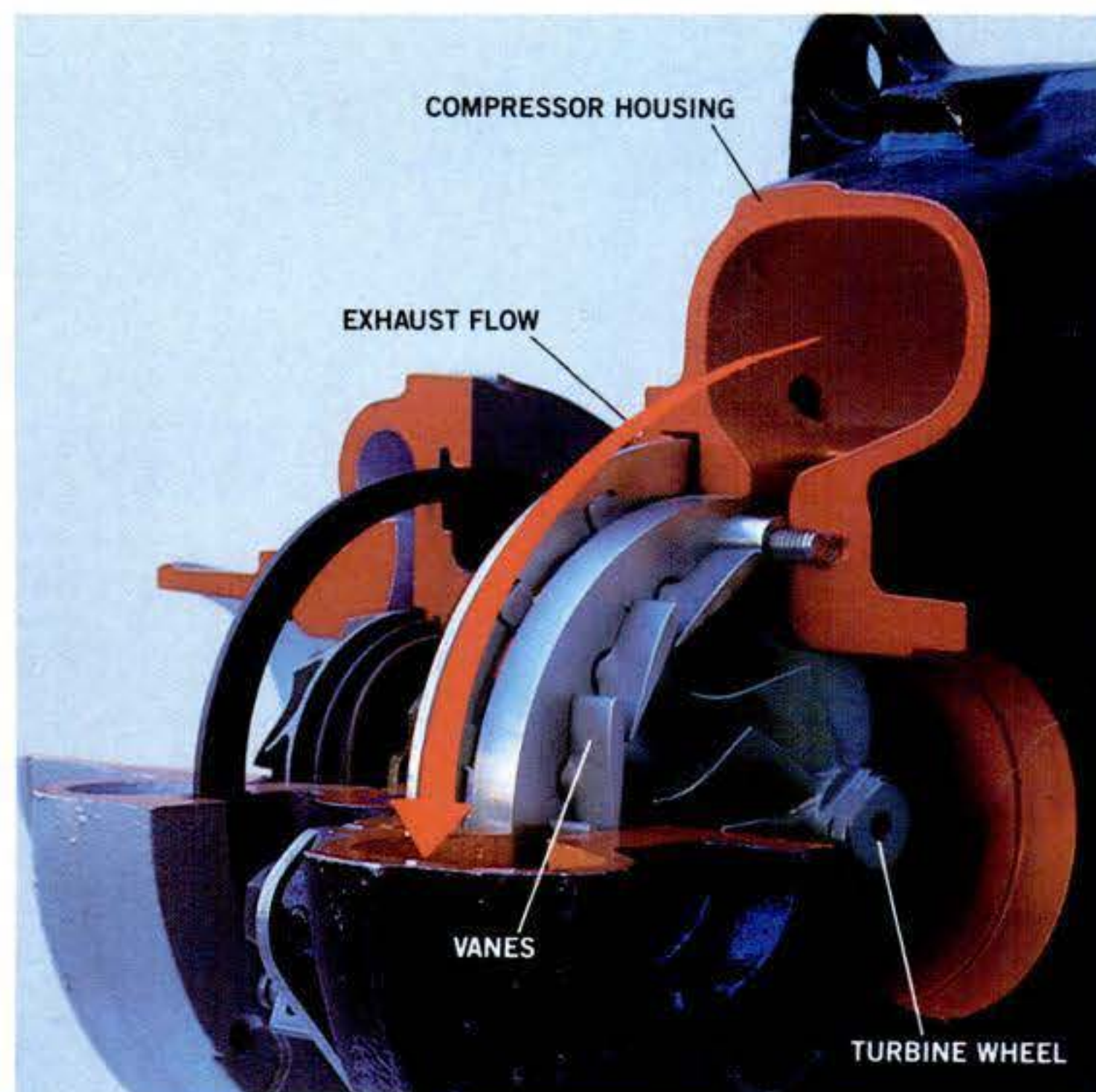


Get More From Life...Buckle Up!

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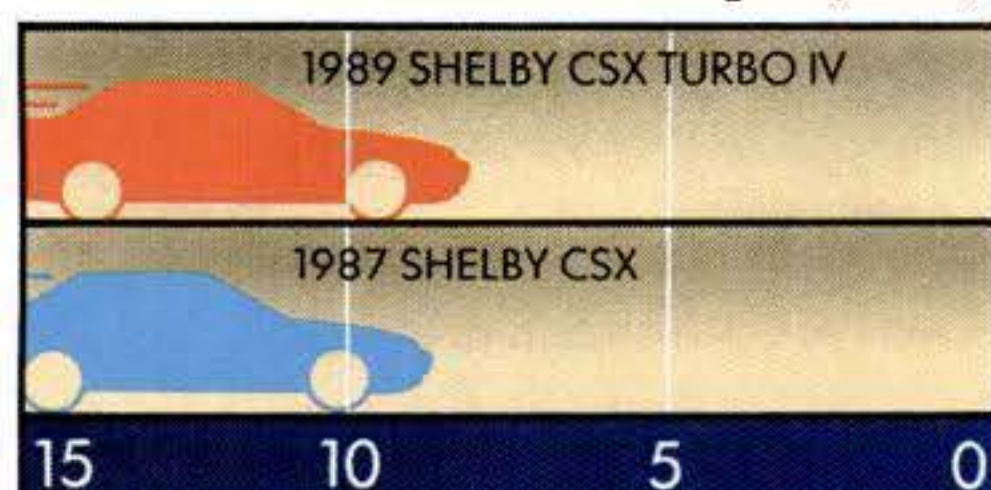
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With vanes fully open (right) the turbocharger channels the exhaust flow for maximum high-revving efficiency. To enhance response, the 12 annular vanes pivot to speed up exhaust-gas flow and force the turbine wheel to operating speed faster.

ACCELERATION 0-60 mph (sec.)



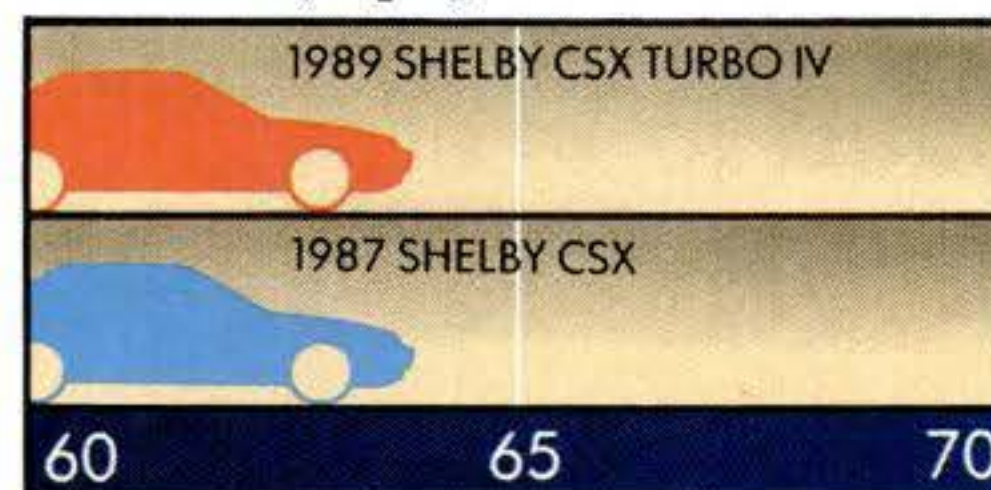
BRAKING 60-0 mph (ft.)



DOUBLE LANE CHANGE (mph)



SLALOM (mph)



and volume of the unit meant the turbine shaft accelerated slowly, so response suffered. Later Chrysler used a lighter turbocharger that improved response, but was still far from ideal. Though the engine produced 142 hp, it still was sluggish in response to throttle commands. In 1987 Chrysler began using the Turbo II system, which sported an intercooler that reduced the temperature of the pressurized air and raised its density to allow higher boost pressures. Power output from the 2.2-liter block increased to 175 hp with 175 pound-feet of torque available—but again using a relatively heavy Garrett turbocharger.

Turbo transitions

Each transition for Chrysler was accompanied by a noticeable decrease in turbo lag. But one trade-off particularly bothered development engineers: When a large-volume turbo that promised high horsepower was installed, throttle response was poor. However, a smaller, quick-to-respond turbo lacked the high-output potential of a larger unit. This dichotomy led to the joint development project between Garrett Automotive and Chrysler to engineer the variable-nozzle turbocharger, which essentially takes the best attributes of each turbo design.

The variable-nozzle turbo is based on the lightweight T25 Garrett unit and contains a ring of pivoting vanes surrounding the exhaust turbine. The vanes move on demand to constrict the exhaust flow at low engine speeds and open at high rpm. The principle is something like closing down one end of a garden hose to increase water pressure and make its stream shoot far-

ther. When the turbo's vanes close, the exhaust velocity increases, which spins the turbine wheel quickly to its optimum operating speed.

Principle and operation

While the principle seems simple enough, the actual operation is complicated and requires elaborate electronic controls and specially designed parts. For one thing, because the vanes constrict exhaust flow to increase exhaust gas velocity, additional back pressure in the exhaust is created. If not properly timed this can shut off the engine completely.

It's worth noting that the vanes can't do everything. When the engine is below approximately 1,800 rpm, there is not enough exhaust flow to keep the turbine wheel spinning even with the vanes at maximum constriction. The use of the variable-vane system thus addresses only one component of turbo lag. By giving the turbocharger's turbine wheel enough exhaust-gas velocity at relatively low engine speeds, it is kept spinning. Under these conditions a conventional turbo remains near a standstill. Another component of turbo lag is the inertia of the turbine wheels and the shaft assembly itself. Some earlier efforts, notably the Buick GNX high-output turbocharged V6, experimented with ceramics to lighten the wheel assembly and quicken the speed with which the turbo accelerated. But this fix required exacting manufacturing procedures, and Chrysler, aiming at high production volumes with the VNT, stuck with conventional materials. To take the abuse of 1,650-degree-F exhaust gas,

Continued

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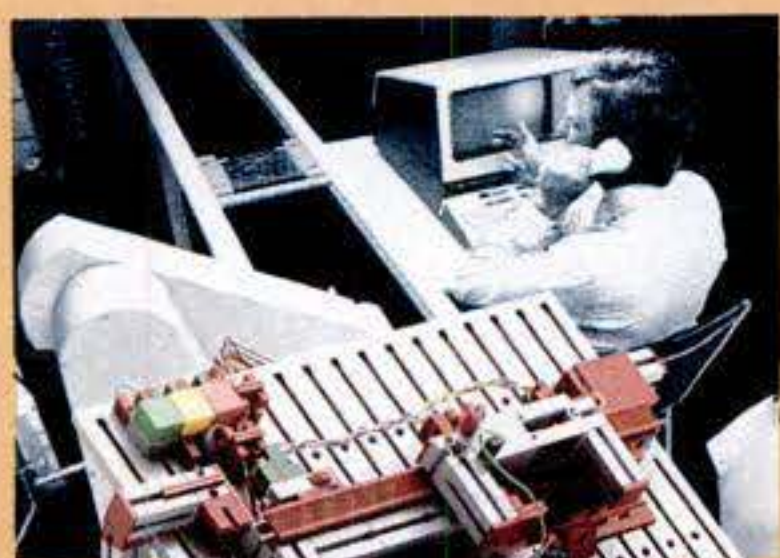
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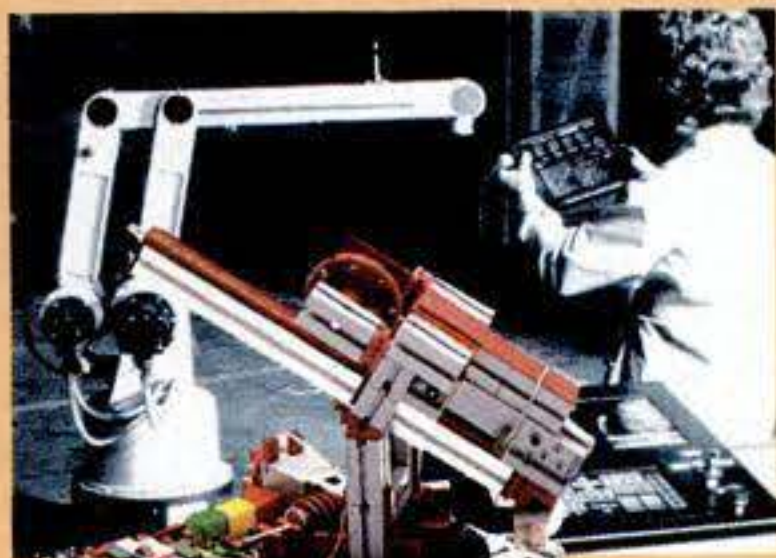
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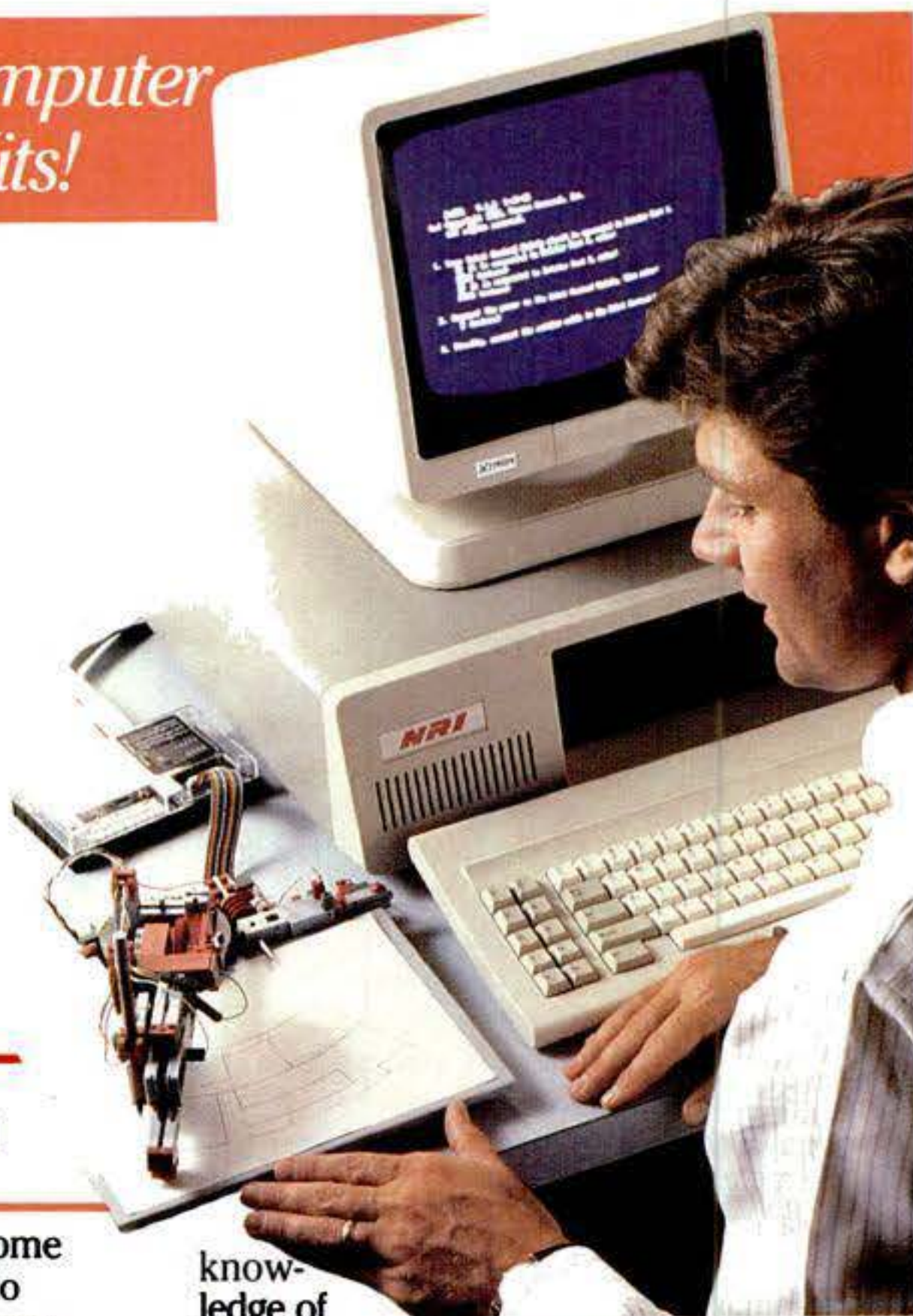
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RIDING ON COMPOSITE WHEELS

The composite wheels on the Shelby CSX represent the latest advance in the evolution of the wheel. While the gold-tone five-point-star wheels look as if they're made of polished aluminum or steel, they are actually molded of vinyl ester/polyester reinforced glass fibers. Randomly dispersed chopped fiberglass is bolstered by continuous strand sheets in areas that require more support. According to Scott Murray, director of engineering at Motor Wheel Corp. in Lansing, Mich., each wheel weighs 18 pounds—five pounds lighter than a similarly styled aluminum wheel and seven pounds less than a steel wheel. Five pounds per wheel may not seem like an astounding weight savings on a 2,800-pound car, but this 20-pound reduction in unsprung weight means the suspension doesn't have to work as hard, and the handling can be made more precise.

"This wheel was designed from scratch and pushes the technology," says Murray. "We started with clay models of what Shelby wanted the wheels to look like, and we engineered the load-bearing structure of the wheels from there." The 11-year development of the Fiberide wheel program at Motor Wheel entailed 5.4 million miles of road testing, as well as extensive laboratory tests on impact, stress, fatigue, corrosion, and how long lug nuts will remain tight. Murray says the composite wheels met or exceeded all criteria when compared with existing aluminum and steel products.

Metal wheels also can resonate like a bell being rung, but Motor Wheel test drivers noted that the Fiberide composite wheel soaked up vibration and tire noise that the metal wheels tended to transmit into the car. Murray claims there is also an added bonus of having wheels that will never rust, corrode, or tarnish and will require a minimal amount of maintenance.—*Brian Nadel*

G WHIZ!

To compare the throttle response of the engines in our test, the POPULAR SCIENCE test team used a special tool that is ideal for the task. The g.Analyst, made by Valentine Research in Cincinnati, measures and records lateral acceleration in units of g. It is sensitive enough to pinpoint minuscule car-to-car performance differences.

The g.Analyst consists of two black boxes linked by a data cable. Power comes from the car's battery via the cigarette lighter outlet. One box mounts flat on the car's floor—close to the car's center of pitch, roll, and yaw



The Shelby Shadow CSX is fitted with composite wheels (top), reducing the car's unsprung weight. The g.Analyst (left) uses three perpendicular accelerometers and sophisticated electronics to detect acceleration changes as small as 0.01 g.

—usually hidden under the passenger's seat; three precision accelerometers within the device sense fore and aft, lateral, and vertical motions of the vehicle. Acceleration readings are recorded 10 times per second and are accurate to within two percent, according to Valentine. These electronic transducers are not fooled by combination maneuvers such as braking and cornering—and the g.Analyst's data reduction circuits correct for the car's pitch and roll. The g.Analyst displays elapsed time and the magnitude of g's the car experiences. Also, a grid of dots plots longitudinal and lateral g's on an electronic graph. Four different analysis modes are available: acceleration and braking versus time; cornering force versus time; a 3.5-second trace of cornering, brak-

ing, and acceleration; and a cumulative plot of the three variables. In addition, it is possible to transfer the data to a personal computer for storage and analysis.

The g.Analyst stores up to eight minutes of driving dynamics in its 16-kilobyte memory. Record, fast-forward, play, rewind, and stop controls—like a VCR—provide access to the data. Maneuvers can be replayed many times for analysis.

To study throttle response, we established a steady cruising speed of 30 mph, started the g.Analyst recorder, and then, as the throttle was pressed to the floor, hit the "now" control button. This placed an electronic marker in the memory corresponding to the start of the throttle response test.—*Don Sherman*

the vane-control mechanism is made of cast stainless steel, and the ring that the vanes sit in is made of a variety of hardened stainless steel.

Early in the development of variable-vane technology, Garrett engineers noticed that the wake produced by each vane was causing the tip of the turbine wheel's blades to break up. Tests using holographic films of the wheel

led to a redesign of the wheel with a more sturdy structure.

The Shelby CSX Turbo IV system is calibrated to keep the turbine wheel spinning at about half its maximum 177,000 rpm under partial throttle conditions. This requires careful control of the vacuum actuator that positions the vanes. For example, at about 2,700 rpm and a steady speed of 35 mph, the

engine throttle is barely open, exhaust flow is minimal, and the vanes are partially shut. A stab at the throttle momentarily closes the vanes to their minimum openings, increasing back pressure and choking the engine for an instant. In fact, for this fraction of a second, power actually drops off. But then the vanes quickly open to the best setting, spinning the turbo up to

POPULAR SCIENCE TEST RESULTS

1987 Shelby CSX

1989 Shelby CSX Turbo IV

ACCELERATION and HANDLING

0-30 mph (sec.)	3.0	3.4
0-60 mph (sec.)	8.1	8.7
30-50 mph (sec.)	14.0	15.1
50-70 mph (sec.)	9.1	11.0
Double-lane change (mph)	56.6	
Slalom (mph)	64.0	
Road holding (g)	0.83	

BRAKES

60-0 mph cold (ft.)	166
60-0 mph warm (ft.)	146
60-0 mph hot (ft.)	151

INTERIOR NOISE

Idle (dB)	55
60 mph (dB)	70

SPECIFICATIONS

Engine	2.2-liter I4
Valve train	2 valves/cylinder
Power at engine speed @ rpm	175 hp 175 hp @ 5,200 @ 5,300 210 175
Torque at engine speed (lb.-ft. @ rpm)	@ 2,100 @ 2,400 8.1:1
Compression ratio	

Transmission	5-speed manual
Final drive ratio	3.85:1 3.50:1

CHASSIS

Front suspension	Independent, Mac-Pherson strut, coil spring, stabilizer bar
Rear suspension	Rigid axle, coil spring, stabilizer bar
Steering gear	Rack and pinion, power
Turning circle (ft.)	40.7 33.9
Brakes	Disc, disc

EPA MILEAGE

City	20	17
Highway	28	25

DIMENSIONS

Wheelbase (in.)	97
Length (in.)	171.7
Width (in.)	67.3
Height (in.)	52.7 52.0
Curb weight (lbs./distribution (% front: rear))	2,823/ 2,690/ 63:37 63:37
Fuel tank (gal.)	14
Interior volume (cu. ft.) distribution (% front: rear)	88.7
Trunk volume (cu. ft.)	13.2

PRICES, PARTS, and SERVICE

Base price	\$15,633/\$13,495
Price as tested	\$16,856/\$13,495
Major options (over \$100)	Recaro seats \$727 225/50 VR15 tires \$466*

PS SERVICEABILITY

Total of 12 (maximum of 60 points) items	40
Best feature	Roomy engine compartment
Worst feature	Hose and spark plug access

SPARE-PARTS COST

Brake pads, front	\$ 62
Brake pads, rear	94
Front shock/strut insert (each)	170
Front fender	92
Alternator	270
Fuel pump	104
Ignition module	350
Grille	320
Front bumper	250
Windshield	401
Taillight lens	22

speed. Within about 0.4 second, according to Chrysler, the turbo is at maximum speed, pumping extra air into the engine.

This is in dramatic contrast to the standard turbo, which responds to a wide-open throttle with a slow run-up of the turbine wheel that can easily take 1.5 seconds. Another difference between the two systems is how they limit maximum boost pressure. The VNT vanes close to isolate the turbine wheel from the exhaust flow to reduce boost. In the more basic turbo setup, a waste gate opens to dump excess turbocharger pressure at high speeds.

Both turbos use a water-cooled center bearing to cure a problem common with earlier turbochargers: heat buildup in the unit following a quick shutdown—such as using the car for short trips. This was sometimes severe enough to carbonize the lubricating oil and lead to bearing failure.

Theory and practice

All this looks good on paper, but we were more interested in how each engine performed at the track. The standard-turbo Shelby CSX was a late-1987 model rated at 175 hp at 5,300 rpm, with 175 lb.-ft. of torque available at 2,400 rpm. The 1989 Shelby CSX is powered by the new Turbo IV VNT system that extracts the same 175 hp out of the 2.2-liter engine, but has 210 lb.-ft. of torque at lower engine speeds.

The numbers are deceptive. The higher torque rating of the VNT-equipped engine is programmed to come in at lower engine speed, then decrease as the engine peaks. This saves wear and tear on the car's five-speed manual transmission, which is near its limit of torque capacity, according to Chrysler engineers.

Our efforts with the g.Analyst demonstrated both the advantages and disadvantages of the VNT. In a second-gear run-up, starting at 3,250 rpm at 30 mph, the constricting vane action of the VNT was noticeable as the old-style turbo accelerated stronger for the first 0.8 second (see graph). Then the VNT-equipped car jumped ahead and reached full acceleration in 1.3 seconds, a half second faster than its older sibling without the VNT.

A similar run in fourth gear proved the VNT to have an even greater advantage over the standard turbo, because the initial speed of the turbine wheel was lower at the point the throttle was opened. And in our top-gear passing test the VNT-equipped Shelby CSX excelled, taking 9.1 seconds to accelerate from 50 to 70 mph, nearly two seconds quicker than the standard-turbo Shelby CSX.

Continued

Un-Paralleled Parking.



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with four-wheel
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Turbo to go *Continued*

The VNT proved its worth, but our comparison cars—the supercharged Thunderbird and the atmospheric-pressure Laser—ended up with bragging rights for real-world throttle response.

Neither of the turbocharged engines came close to the supercharged engine in terms of throttle response. The belt-driven blower on the Thunderbird Super Coupe runs in lock step with the crankshaft, but at 2.6 times its speed. When the throttle is opened, a valve dumps the air that is already moving and circulating in a bypass loop through the supercharger directly into the manifold, giving near-instantaneous boost. The Super Coupe reached its maximum acceleration in one second in second gear, the fastest time we measured for a boosted car.

The ability to pump air quickly into the manifold not only means that lag time is reduced, but also that the supercharger can effectively offset the sluggishness that comes from lowering the compression ratio on force-fed engines. However, reduced fuel economy is the price paid for the extra horsepower that's produced when using a blower on the engine. For the most

part, this is due to the parasitic drag of the supercharging mechanism, which spins whether its pressurized air is being used or not. At full boost the blower consumes up to 60 hp, but at a light throttle, say cruising at 55 mph, it drains a mere half horsepower, according to Ford.

Most surprising was that under some conditions, the low-powered Laser responded the best, despite having the slowest 0-to-60-mph performance of the group. Starting with the engine running near its optimal power band at 30 mph in second gear, the Laser took 1.4 seconds to reach maximum acceleration. In higher gears it reached peak acceleration in as little as 0.8 second, then leveled off to a stable rate where the rising engine torque was balanced against the vehicle's aerodynamic drag as the speed increased.

Better, but...

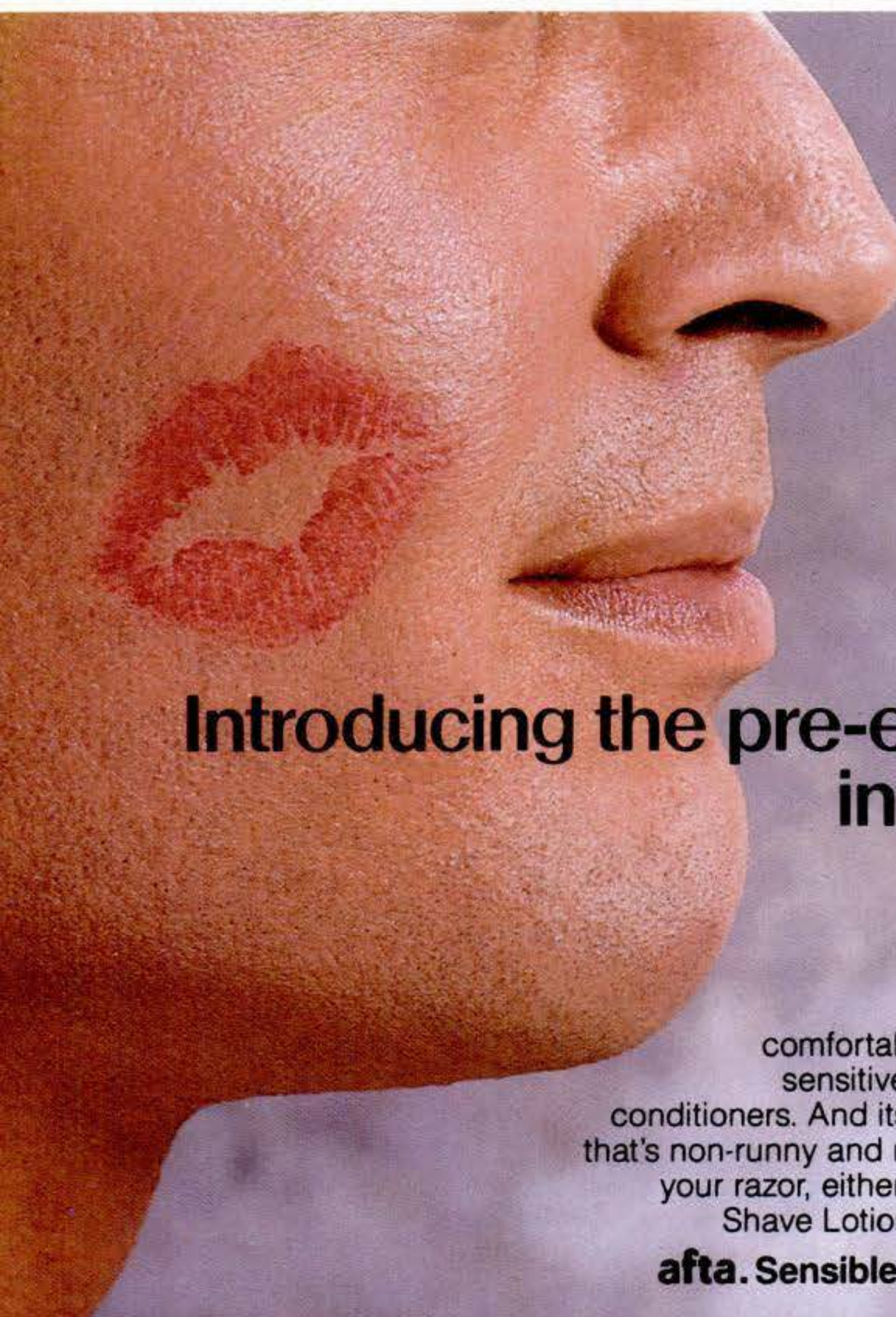
Our conclusion: Controlling the exhaust flow with the VNT is clearly superior to conventional turbocharging, and with proper calibration it is capable of making the turbo more acceptable for real-world driving conditions. Its biggest advantage is responding to

a wide-open throttle at medium engine speeds—a typical passing situation on the highway.

On the other hand the VNT is non-operative at low engine speeds. There remains a noticeable hesitation before the system builds boost in the early stages as compared with the standard turbo and overall when compared with supercharging. Even a half second can seem like a long time when you're in the left lane passing a truck on a two-lane road.

Last, like any new technology, it has to work in harmony with the rest of the car. The Shelby CSX was a marginal car at best. The 210 lb.-ft. of torque easily walked the front end around under full-throttle acceleration like a dog on its leash. Stiff springs, shocks, and sway bars all made for quick 56.6-mph double-lane change and 64.0-mph slalom scores, but were rough on the posterior. With so much power, lack of steering precision made the car uncomfortable. Chrysler's balance-shaft four-cylinder engine, smoother transmission, and better worked-out suspension would help do the VNT justice.

But when you want to step out to pass, the VNT is the answer. **P 5**



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"Say, Smokey—"

A clinic on cars by Smokey Yunick, America's most famous mechanic

Knock-out

I've been experiencing an engine knock problem with the two-liter engine in my 1987 Pontiac Sunbird SE. The noise sounds like gurgling and occurs most often when the engine is warm and under load.

Kurt E. Stalhuth, Euclid, Ohio

Spark knock is what you're hearing. Whether it is called detonation or ping-ing, it's the same thing. The fuel you're using may not be up to manufacturer's specifications and can't handle the compression. In your car the air-fuel ratio and spark timing are computer controlled and may need a correction in the programmable read-only memory, or PROM, chip. It's also possible that one of several sensors is malfunctioning and providing the PROM with bad information on variables such as air or water temperature, air-fuel ratio, or engine load and rpm. There is no way to diagnose this problem except with specially designed equipment that can communicate with the engine's computer. All Pontiac dealers—and many independent repair shops—have this equipment and can correctly diagnose the problem. The car's emission-control equipment must also be working properly because it too can affect the air-fuel ratio.

Low pressure

The oil pressure light in my Ford Tempo LX takes a long time to go out and the valves to stop knocking on a cold start-up. Two dealers claim this is a normal condition caused by an oil bleed-down system in the engine, and that no damage to the engine will occur. What is your opinion?

Steve Bednarz
Schaumburg, Ill.

All I can say is what I've been saying for years. I think all engines should have oil pressure before starting. An engine with this type of oil system would last a lot longer ["Say, Smokey: What's the Car Engine of the Future?" March]. Also, the colder it gets, the worse this problem gets.

Advanced pickup?

I have a 1985 Toyota pickup that pings under normal load. When I floor the

accelerator pedal, the engine runs and sounds fine. The engine has been doing this for 3½ years. Every time I take it to the dealer, the mechanics set the timing and tell me it's fixed, but it still pings. Should I just buy some ear plugs?

H.W. Barr, St. Louis, Mo.

You've got an ignition advance problem. When you floor the accelerator pedal, the amount of vacuum the engine produces drops, and the ignition timing is retarded. At intermediate load (between 5 and 14 inches of vacuum) it sounds as if you have too much ignition advance. Check the spark calibration of the distributor against the shop-manual specifications, as well as the emissions-control devices and air-fuel mixture.

Tough starter

My 1983 Pace Arrow Class A motor home has a Chevrolet 454W engine with 43,000 miles on it. The engine refuses to turn over when it's hot, even if all of the batteries are interconnected. When cold, a single battery will easily start the engine.

Clyde Williams, Tampa, Fla.

Your problem is heat, which reduces the starter motor's power. You should do all that is possible to cool the starter area: Heat shields and air ducts are the best remedy. Insulating exhaust headers and pipes also helps. Shorter, heavier battery cables and an extra solenoid connected directly to the field terminal on the starter can help. All of these fixes take time, and it's hell to work in the confined space available, but they provide the only relief.

Slow shifter

I have a 1983 Datsun with a standard transmission. When the car sits idling for a couple of hours in zero degree weather, the transmission oil gets very thick, which makes the car hard to shift. After about a mile of driving, the oil warms up enough so I can shift with normal effort. Can I use a 5W-30 oil in the transmission rather than the 80W-90 gear oil that is recommended by the manufacturer?

Larry Best, Blue Grass, Iowa

If you play around with lube, I'd rather see you use automatic transmission
Continued

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fluid that's light and tough as well. But when you experiment be prepared for a learning curve. For example, the transmission seals may leak with a different specification lube.

Whipped-up Quad 4

I have a 1989 Pontiac Grand Am equipped with the Quad 4 engine. The car runs fine except in cold weather when a white foam forms on the dipstick. In very cold weather, ice forms at the end of the stick, making it nearly impossible to check the oil level. The dealer and zone manager claim this is normal.

Gary Sawosik, Westford, Mass.

It sounds as if you're using the car mostly for short runs. All engines accumulate moisture when they cool off, especially in high-humidity climates. Engine heat vaporizes this water and very little dilution of the oil occurs. In reference to the oil dipstick freezing, I would suggest a synthetic lubricant like Mobil 1.

No tow

My Oldsmobile Delta 88 has heavy-duty coil springs and shock absorbers. Even so, the car is not able to tow a 1,500-pound camper without pounding the rear occupants with sharp jerks on every bump. My 1976 Chevrolet Nova with a leaf-spring suspension can do the job fine.

A.J. Schulte, Ocean View, Del.

I don't think that coil springs versus leaf springs makes much difference in towing. Assuming you have springs and shocks that are up to the job, your car should sit close to its normal angle with the trailer attached. It is important that the tow ball has 15 to 20 percent of the trailer's weight on it. My guess is that the big difference in the two vehicles is the trailer hitch itself.

Cimarron stall

My 1987 Cadillac Cimarron with a 2.8-liter V6 stalls after running for about four minutes regardless of weather conditions. If I try to restart it, blue smoke comes out, in addition to a chlorine smell. My dealer says it is normal, but my 1982 Cimarron with a 1.8-liter engine has never given me a problem and runs fine after 189,000 miles.

Joe Duran Jr., Hernandez, N.M.

There is a big difference in the fuel-injection systems between your new

car and the old one. The new one has computer-controlled fuel injection and a more complex emissions-control system. I can't specifically tell you what to do, but I suspect your engine is being over-fueled on cold start-up. My advice is to find a General Motors dealer with the equipment and schooling to diagnose and repair the car properly.

Racked to the Max

I own a 1987 Nissan Maxima with 38,000 miles on it. I recently lost control of the car on a snow-covered parkway after the rack of the car's rack-and-pinion-steering mechanism broke in two. The underside of the rack was blue as if it had been heated with a torch.

Tony Lorenzo, Beachwood, N.J.

Rack-and-pinion steering is used successfully on most race cars and on many production automobiles today. Durability has been pretty good, but the mechanism is much more fragile than frame-mounted worm-and-roller steering boxes. Rack-and-pinion steering systems are lighter and give better steering geometry. I can't guess as to the reason for your unit's failure, but I'm not apprehensive about the use of rack-and-pinion steering in general.

Warm Safari

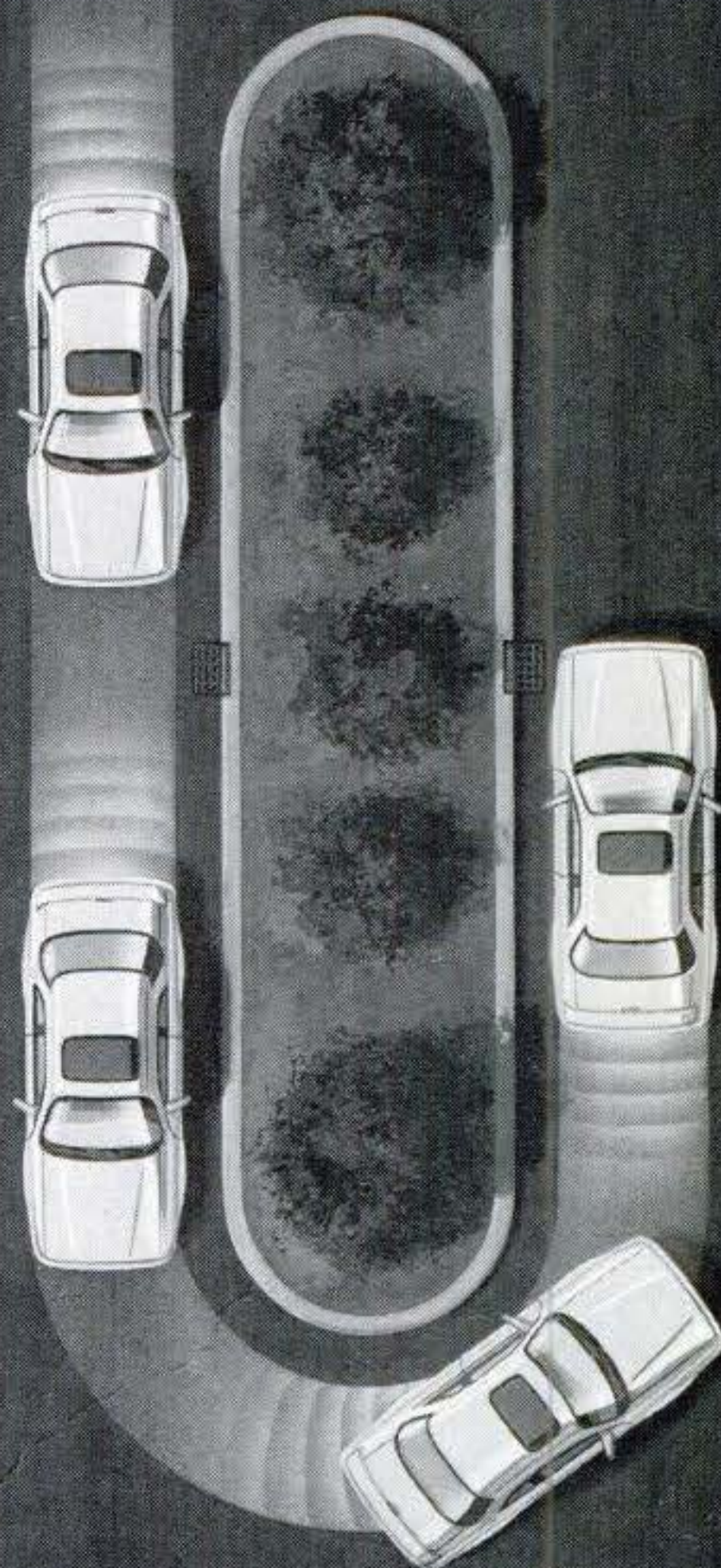
My 1988 GMC Safari minivan has front and rear air-conditioning outlets that put out warm air when the outside temperature is above 85 degrees F. What should I do?

Dennis R. Lavers, Ardmore, Okla.

I think you should check to make sure the plenum door closes when you move the temperature control lever; you should be able to hear it close. Then try lowering the setting on the air-conditioner pressure switch to increase the amount of time the compressor operates. The only problem is that in humid areas this can cause the air conditioner's evaporator to ice over. But other things, like having a dark-color van or driving slow under load, reduce the air conditioner's ability to cope with warm weather. The air-conditioning system on this van may be too small for its application. But bigger isn't always better because an A/C eats lots of power, which can affect mileage and performance in a big way.

Got a car problem? Send it to "Say, Smokey—," POPULAR SCIENCE, 2 Park Ave., New York, N.Y. 10016. All letters are read, and those of widest interest are answered in this column. Due to the large volume of mail, Smokey cannot reply to letters not selected for publication.

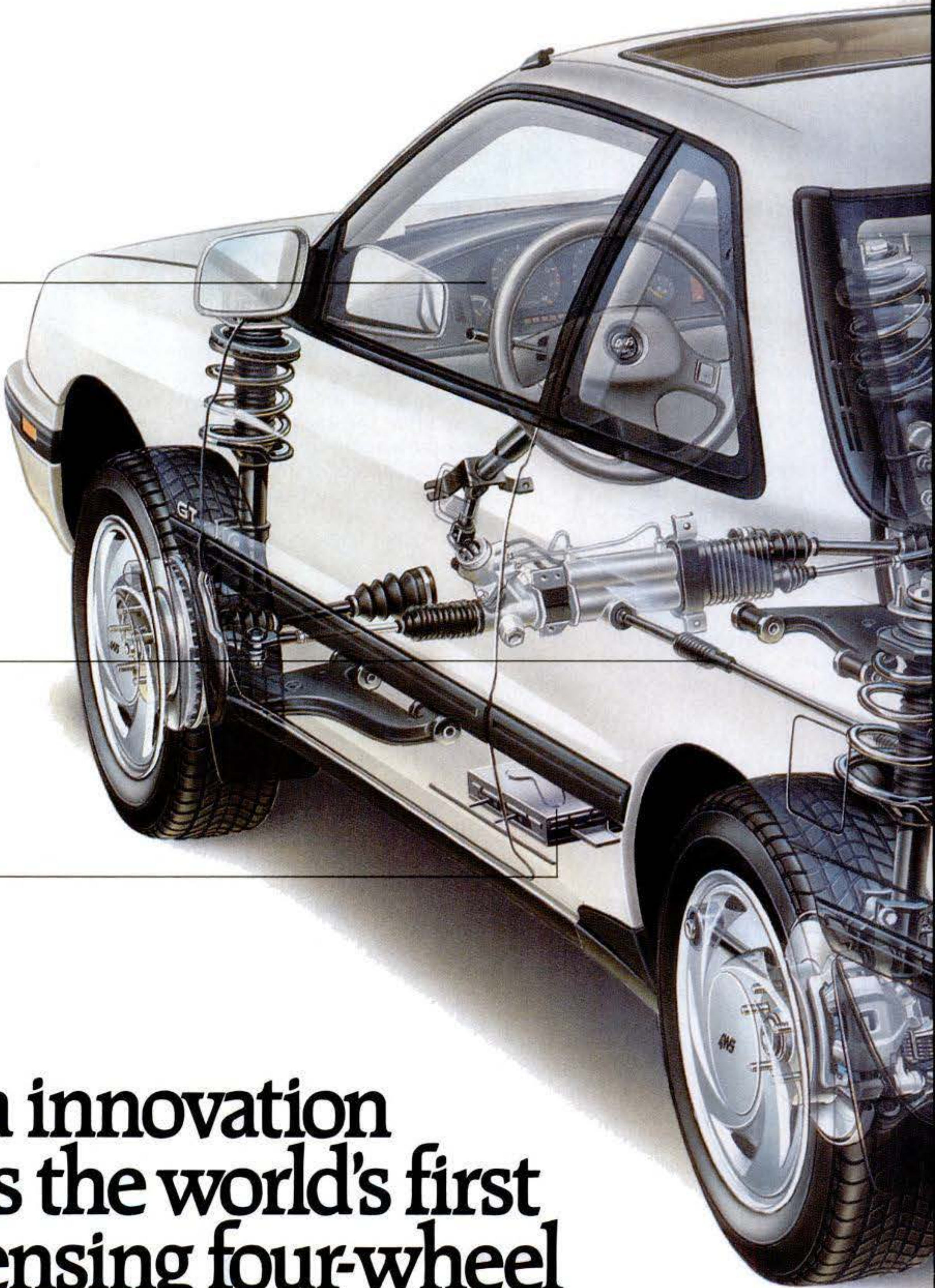
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and send data to
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**STEERING ANGLE
TRANSFER SHAFT:**
rotates the gears in
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to coordinate front
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gives signals to the
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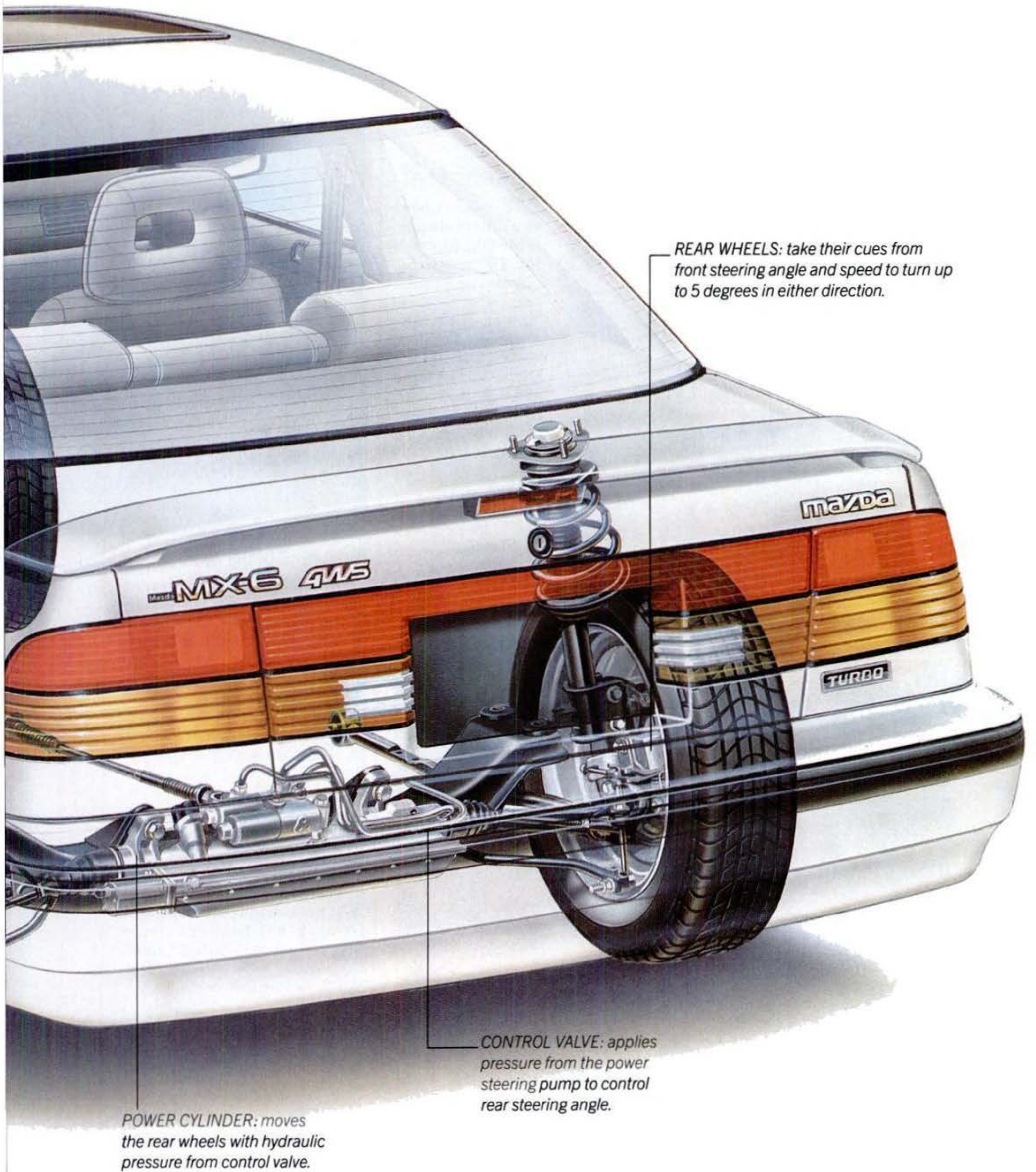
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opposite direction of the front wheels to provide increased maneuverability for situations such as U-turns and parallel parking.

The turbocharged Mazda MX-6 4WS. It takes handling precision, control and performance to levels that can only be described as "exhilarating." And more importantly, raises your personal driving enjoyment to a level even beyond.



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What's New



◀ Instant tent

Two operators can erect this portable big-top tent in 15 minutes, claims the French company Gillard. The 59-foot-diameter Mobile Space comes folded on a truck. An elevating system lifts and unfolds the tent, and the truck drives out the door. Société G. Gillard, Z. A. rue des Peupliers, BP 7, 77590 Bois-le-Roi, France.



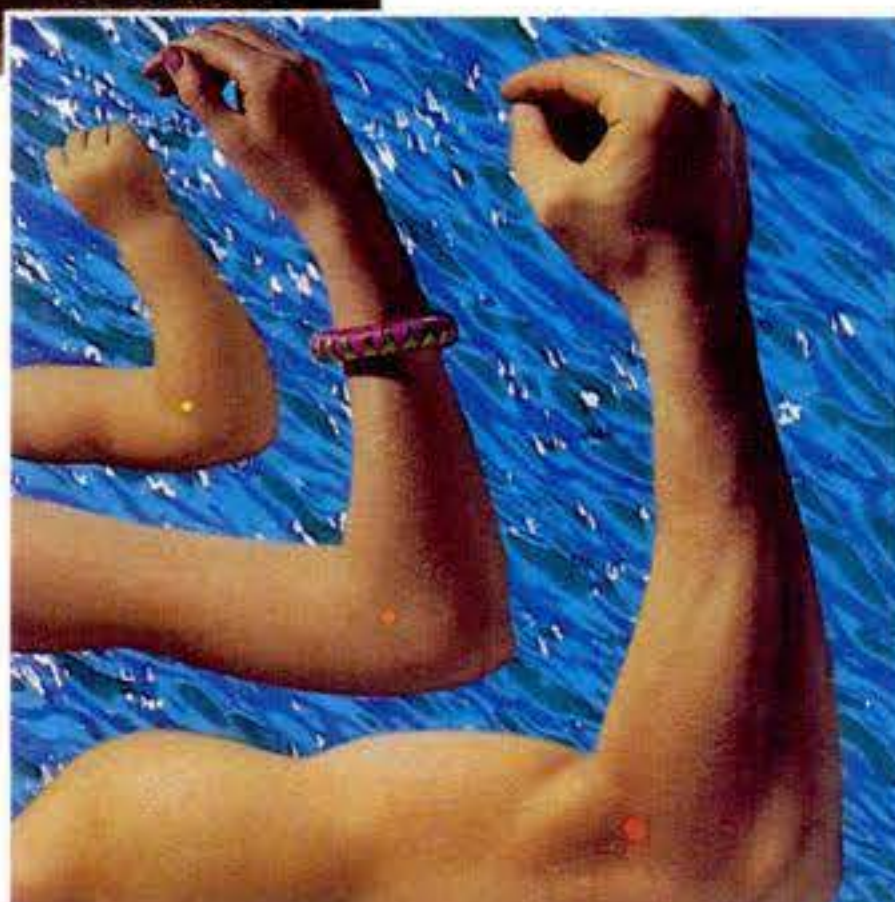
Home dome ▲

You and 29 friends can sit inside this 10½-foot-high 16-foot-diameter sky dome made of polyester scrim. A blower fan keeps the lightproof dome inflated while the steel-globe star projector displays two sky shows. Price: \$8,500. Hammacher Schlemmer, 147 E. 57 St., New York, N.Y. 10022.



Touch tones ▲

Each of the eight fingertips on these gloves plays a different note when tapped. Sounds come out of speakers on top of the battery-operated Musical Hands (\$23 a pair). Majon International, 23135 Samuel St., Suite 7, Torrance, Calif. 90505.



◀ Spot check

As sunscreen applied over these adhesive Sun Spots wears off, the spots change from yellow to red. That helps protect sunbathers from burns, says Sun du Jour, 250-L Corporate Blvd., Newark, Del. 19702. A 10-pack costs \$3.



◀ Primed for flight

Serial number NC-4, the first production Starship, leaves Beech Aircraft Corp.'s completion center for a flight test. The all-composite business turbo-prop received a powder-blue primer coat instead of the greenish zinc-chromate primer used on metal aircraft.



Potato chips ►

Scottish inventor George Anderson tests a potato-sized device he designed to measure the bruising real potatoes receive during handling. Data from sensors on the device are stored internally on microchips for later display. A smaller device tests for damage to apples.



High strung ▲

Most stunt kites are flown on two strings—one for each hand. To perform tricks, kite fliers pull on the handles. Not so for the \$220 Neos Omega Revolution 1, which has twice as many lines as a normal stunter. The kite's handles pivot, making the kite revolve, move backward as well as forward, or stop in midair, says Into The Wind (1408 Pearl St., Boulder, Colo. 80302).



◀ X-rays to go

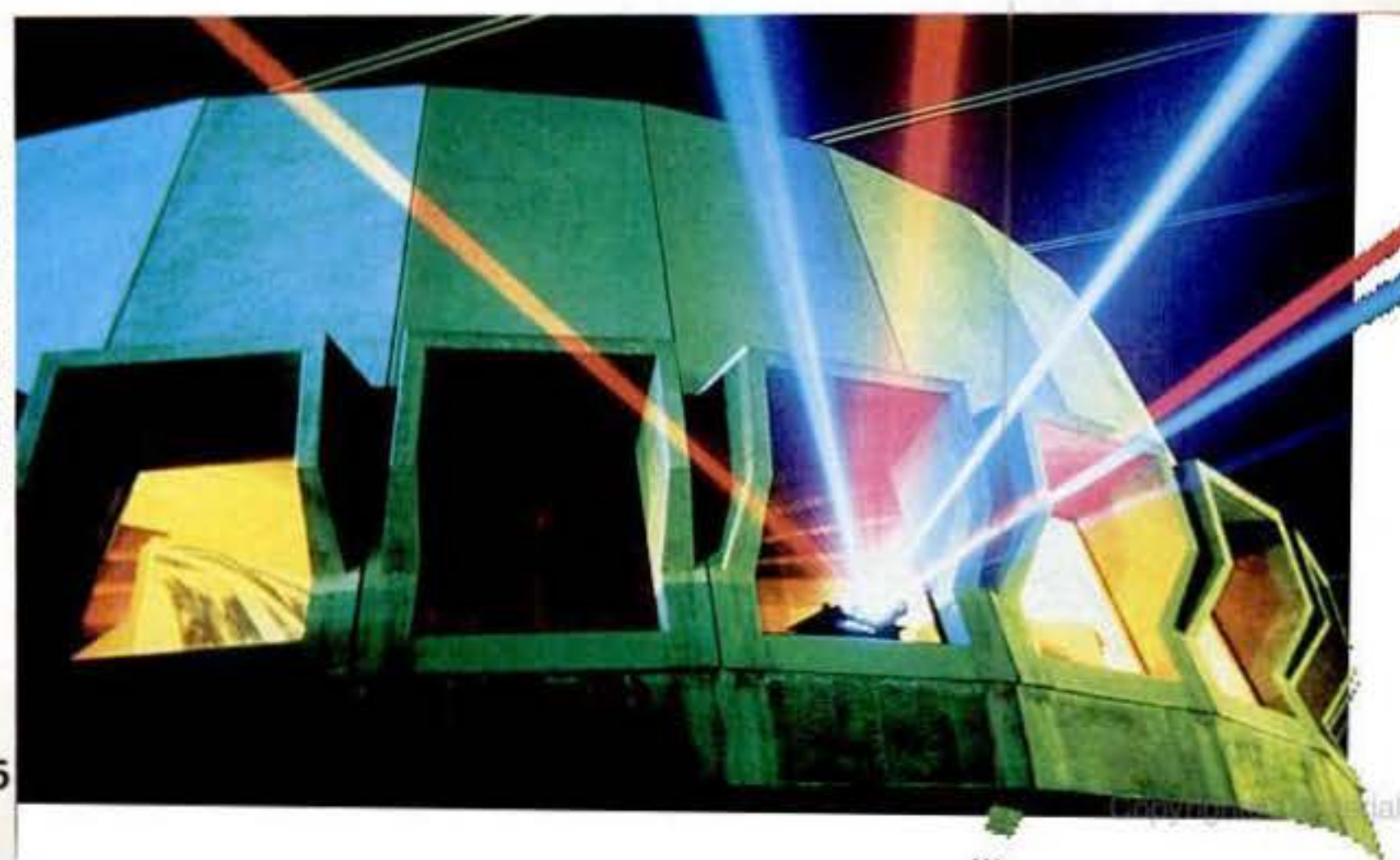
The Xi Scan 1000 is the first commercial hand-held radiographic and fluoroscopic imaging device, says Xi Tech Inc., a medical technology firm that claims the \$18,000 system offers the same image quality as hospital systems costing up to 10 times more. The eight-pound machine could be used by podiatrists, veterinarians, orthopedic surgeons, sports teams, and military field units.

Pilot's planner ▲

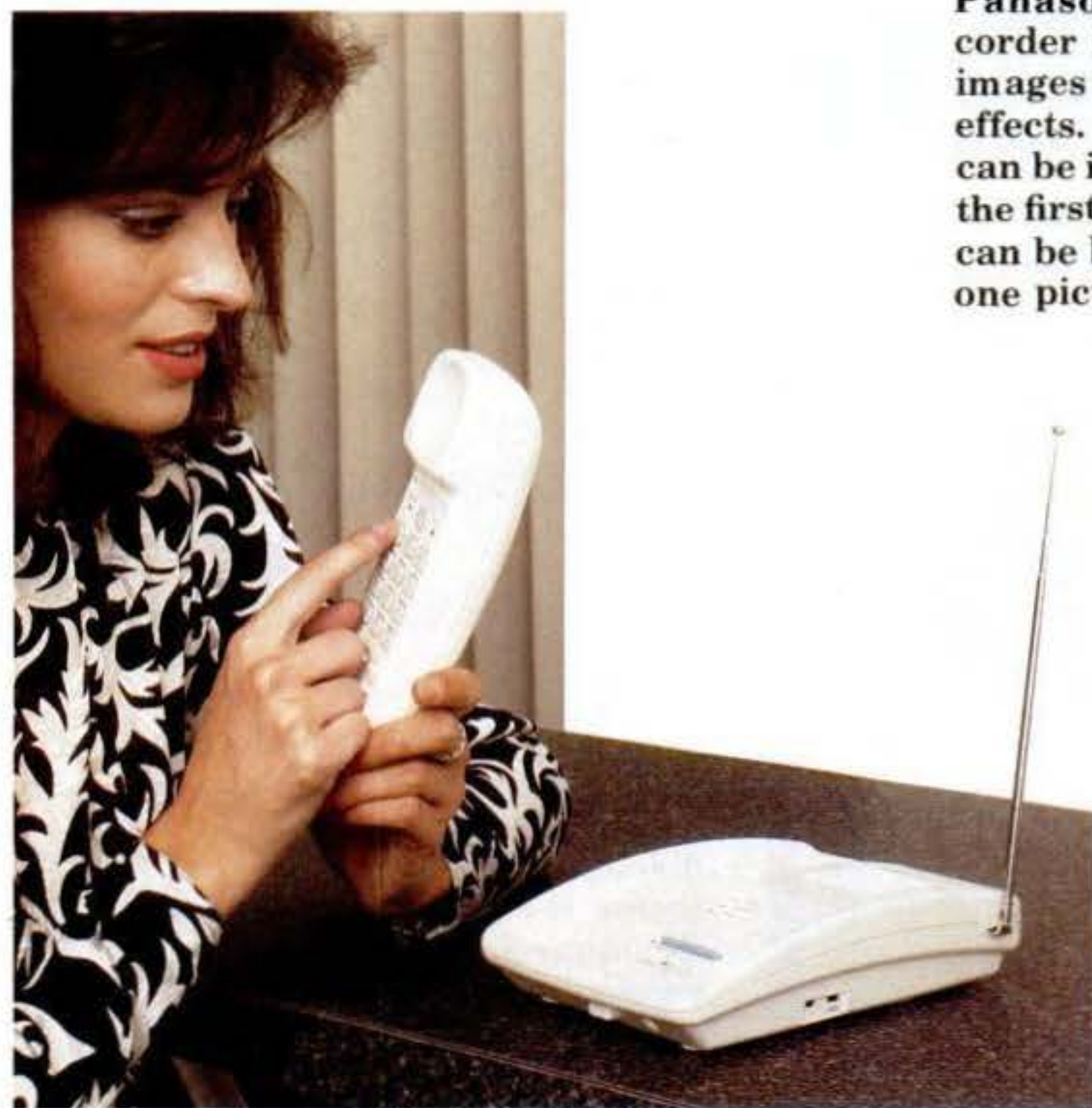
The safest route to and from a target is displayed on a U.S. Air Force control system in the cockpit. The route was mapped out by the Pilot's Associate, a network of sensors and data processors that helps aircraft avoid missiles.

Big screen ►

Laser beams from this control center are projected onto the spillway and surfaces of Washington's Grand Coulee Dam. The laser light show, with music and sound effects, was slated to open on Memorial Day weekend.



What's New ELECTRONICS



Good listener ▶

Speech recognition isn't new to cellular phones. Say a name, and the speaker-dependent phone is trained to know your voice and dial the number. But Uniden's future phone is speaker *independent*. No training is needed, and anybody can dial just by saying a name or speaking the number.



Two-eyed camera ▶

A second CCD camera on Panasonic's PV-535 camcorder lets you record two images at once for special effects. The second image can be inset in the corner of the first, or the two images can be blended together in one picture. Price: \$1,700.



◀ Less than cordless

This cordless phone has memory dialing, hold, a speaker phone, and a two-way hands-free intercom. What doesn't it have? An antenna. The clumsy rod has been removed, but without a loss in distance claims the maker, Cobra Electronics. Price: \$230.

◀ Memo taker

Sony's TCM-27 adds the date, time, and a five-character title to a recording. When the cassette is played, the information is shown on the machine's LCD. A new title can be made every eight seconds, and an indexing system lets you find any segment quickly. Price: \$160.



◀ 3-D entry

Push, pull, yank, and twist—the Spaceball enters your hand movements into a computer as three-dimensional computer-aided-design instructions. Spatial Systems, 472 Old Bedford Rd., Concord, Mass. 01742; \$2,950.

A-V to go ▶

It's an audio-video system for your briefcase or desk: Magnavox's AM-FM-FM stereo radio includes a three-inch LCD color TV. Connectors let you use the screen as a video monitor too. \$449.



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Now it's easy to make your engine run better, last longer. Just add **TUFOIL** to the crankcase. You don't have to shake the container or add an engine flush. Just pour it in and drive away.

Your throttle will get silky smooth ... acceleration will improve. One customer said his car "takes off like a scared rabbit!"

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I keep getting telephone calls from owners of very expensive German diesels wanting to buy stock in our company. They say their diesels are accelerating like nothing they've ever seen before. One said he doesn't have to down shift any more on an annoying hill in his area.

Your car can have more power like that too.

What about additives that claim to be one time treatments that will last the life of an engine? Well, I've been following the scientific literature on lubrication for a very long time. As far as I know, there isn't a shred of scientific evidence for such a claim. So don't believe it!



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Engines last longer with **TUFOIL**.. Our 1976- 476 T-Bird is now at **190,000** miles and purring.

A bunch of customers' cars have now passed **250,000** miles.

Several months ago, a nice man I'd never seen before walked into my office, big smile on his face, sat down and said, "Would you believe **340,000** miles on a **Tufoil** engine?" He went on to rave about how well his engine has been running all these years. I couldn't get a word in edgewise.

It made me very proud.

Recently, a truck driver called in with over **1,000,000** miles on a diesel using **TUFOIL** - Wow!

A customer from Vermont added 10% **TUFOIL** to his sticky mechanical transmission, called in and said he couldn't believe it... "Shifting is like slicing butter now!", he said.

SAAB owners are writing letters praising **TUFOIL** in their "NINES" magazine. They report spectacular improvements in their engines and transmissions!

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One customer put it nicely when he said, "You can hear it...you can feel it!"

PS--Our loyal customers wrote this ad for us. Its full of their comments!

Thanks!

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See **NASA** Tech Briefs for technical details, 1986, 1987 and 1988.

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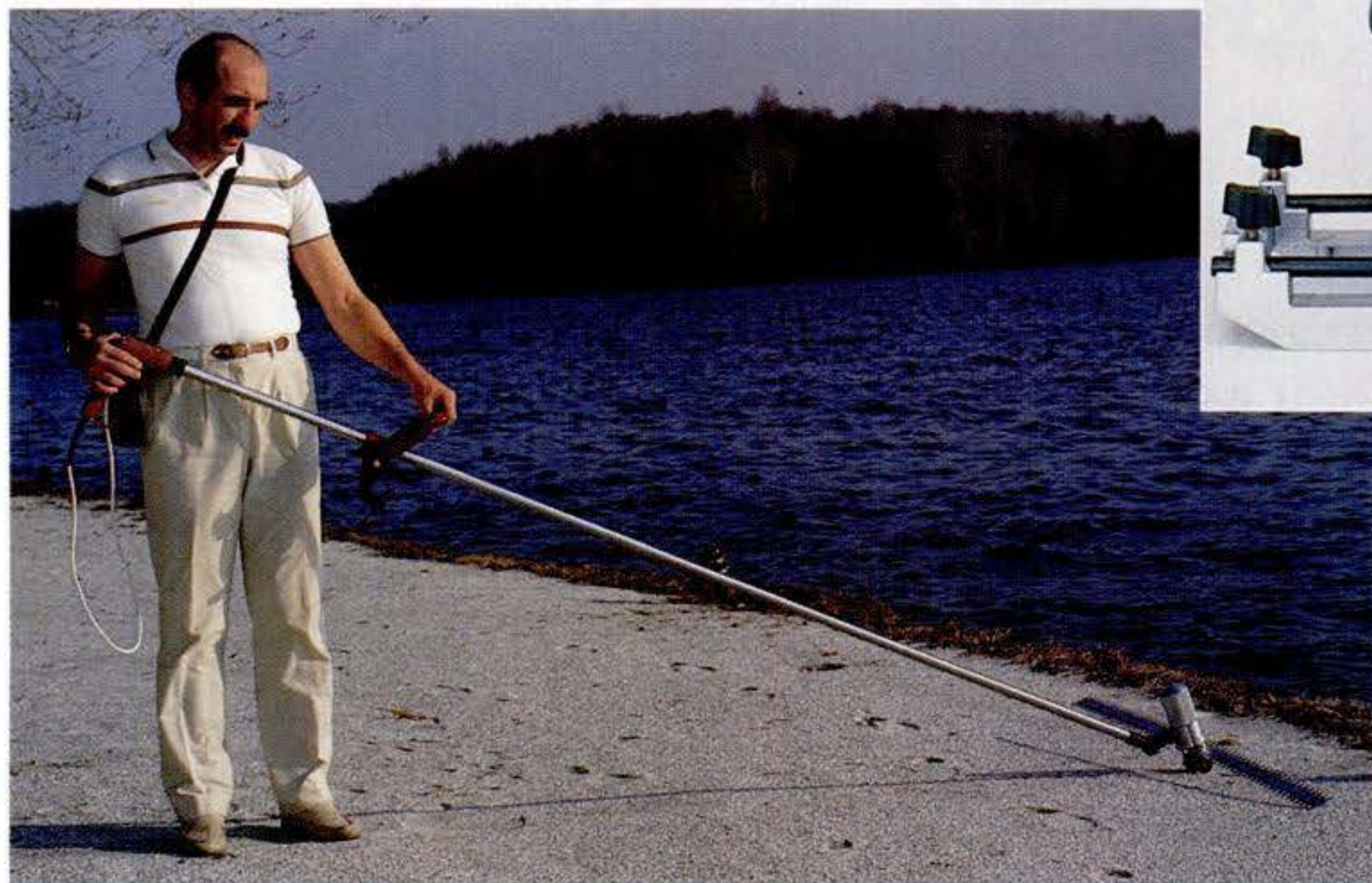
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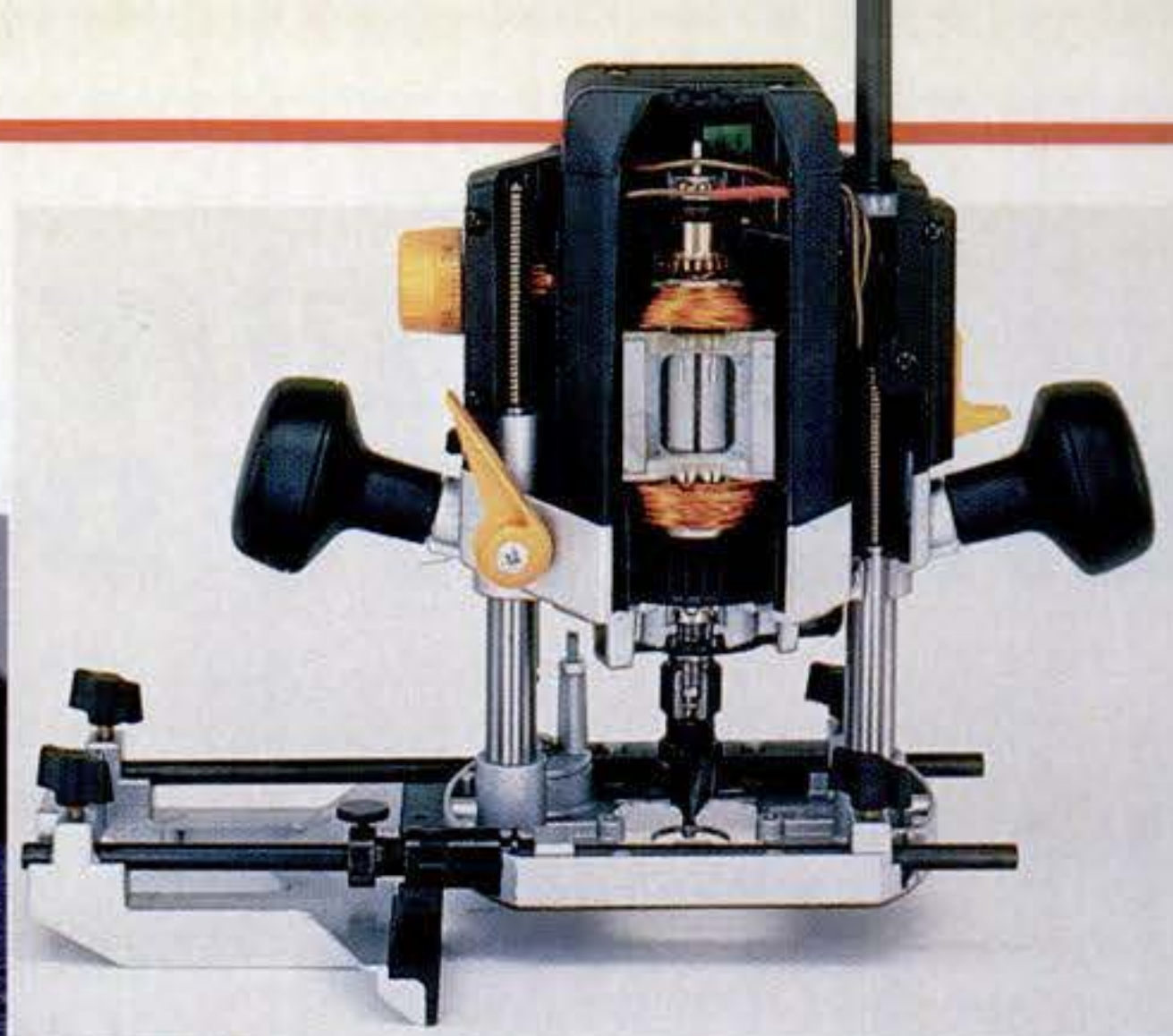
(N.J. residents please add 6% sales tax). Canadians:
Call for the name of our Canadian distributor.

What's New TOOLS



Underwater weeder ▲

You can give aquatic plants a quick haircut with the Water-Weeder. Its stainless-steel blades, powered by a 12-volt battery, cut a four-foot swath. The eight-foot shaft can be extended to 12. Base price: \$300. Waterside Products Corp., Box 876, Lake Mahopac, N.Y. 10541.



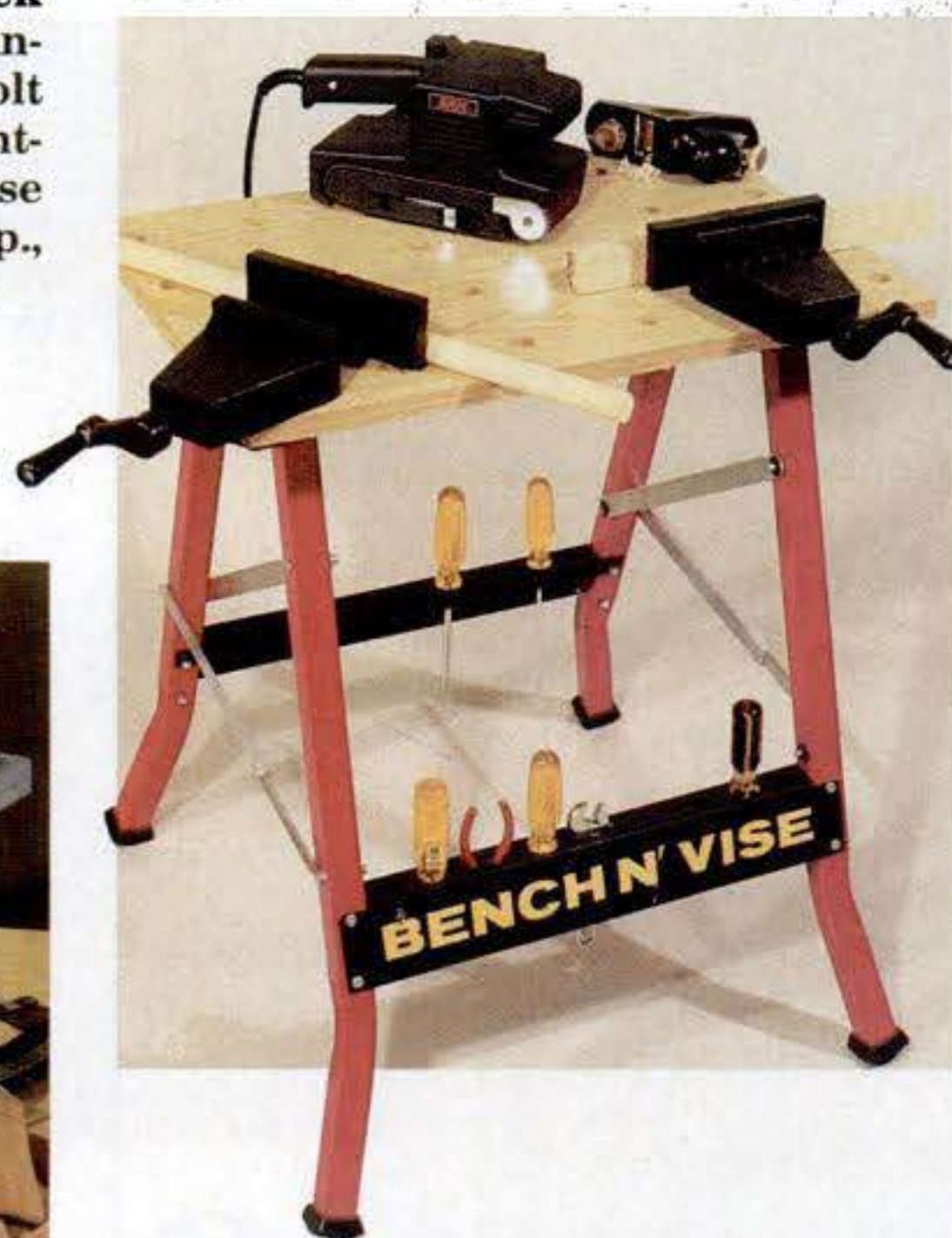
One-horse pro ▲

AEG has introduced its first professional router: a 1/4-inch plunge router with a 6.5-ampere motor. Features: a depth stop adjustable in 0.5-millimeter increments, a spindle lock for easy bit changing, a lever to release or lock the plunge depth, and more. Price: \$278. AEG Power Tool Corp., 3 Shaw's Cove, New London, Conn. 06320.



Bench addition ▲

Delta, best known for heavy-duty stationary tools, expands its line of bench-toppers with a new 8 1/4-inch table saw—big enough to cut a 2x4, even with the blade at 45 degrees. The 13-ampere 4,500-rpm motor means fast and efficient cutting, it's claimed. Delta International Machinery Corp., 246 Alpha Dr., Pittsburgh, Pa. 15238. \$321.

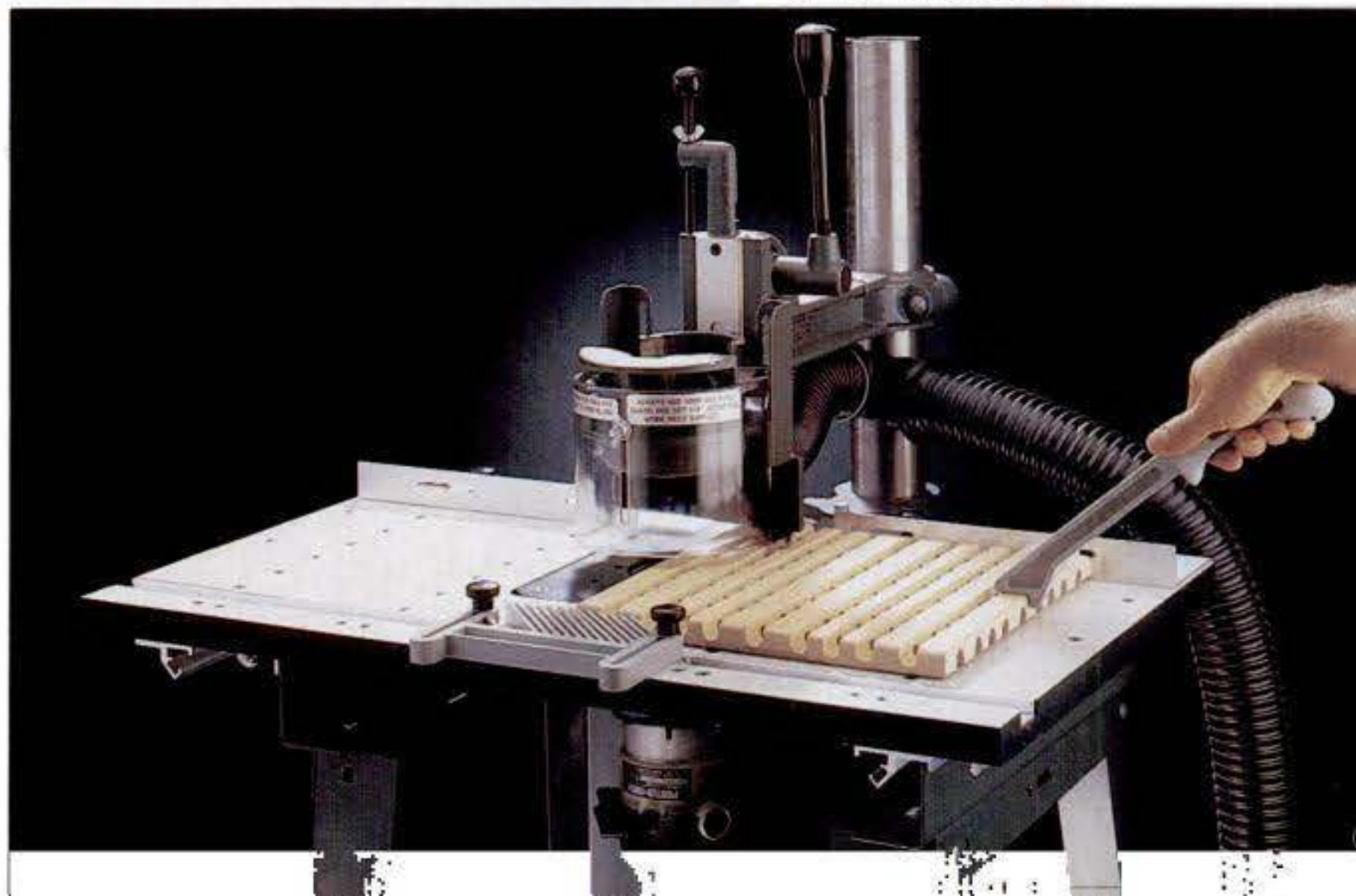


◀ Workbench to go

The Bench N' Vise workbench has pop-out vises and pegs, so you can use the top as a worktable or sawhorse. The model 1042 (\$50) is shown; three other models have different top, vise, and peg configurations. All four fold for portage and stowage. Ashton Products, Box 443, Lisbon, Ohio 44432.

Two-way router table ▼

With your router motor mounted under the table of Shopsmith's Routing System (as shown) you can use it like a shaper; with it mounted on the arm you have a pin router (with a safe view through the plastic shield). The system is \$399. Router (not included) must be round, 2 1/2 to 4 inches in diameter, and no more than three horsepower. (Fence and Featherboard shown are optional.) Shopsmith Inc., 3931 Image Dr., Dayton, Ohio 45414-2591.



What's New HOME

Halogen heater ►

The bright red disc is a halogen burner ["Cooking with Halogen," May], and the Blanco cook top has four of them. With halogen, unlike other electric burners, full heating capacity comes on immediately, with an infinite range of settings. This is the first such top to be UL-approved, says Blanco America, 1001 Lower Landing Rd., Blackwood, N.J. 08012. Price: \$975.



Soft-edge ceramics ►

Italian-made Pillow-Edge ceramic tiles have a slightly rounded surface with bull-noselike edges, which give them a cushioned appearance. The contoured edges make setting easier, says the maker, because slight alignment mistakes are imperceptible. Huntington/Pacific Ceramics, 5204 Airport Freeway, Fort Worth, Texas 76117.

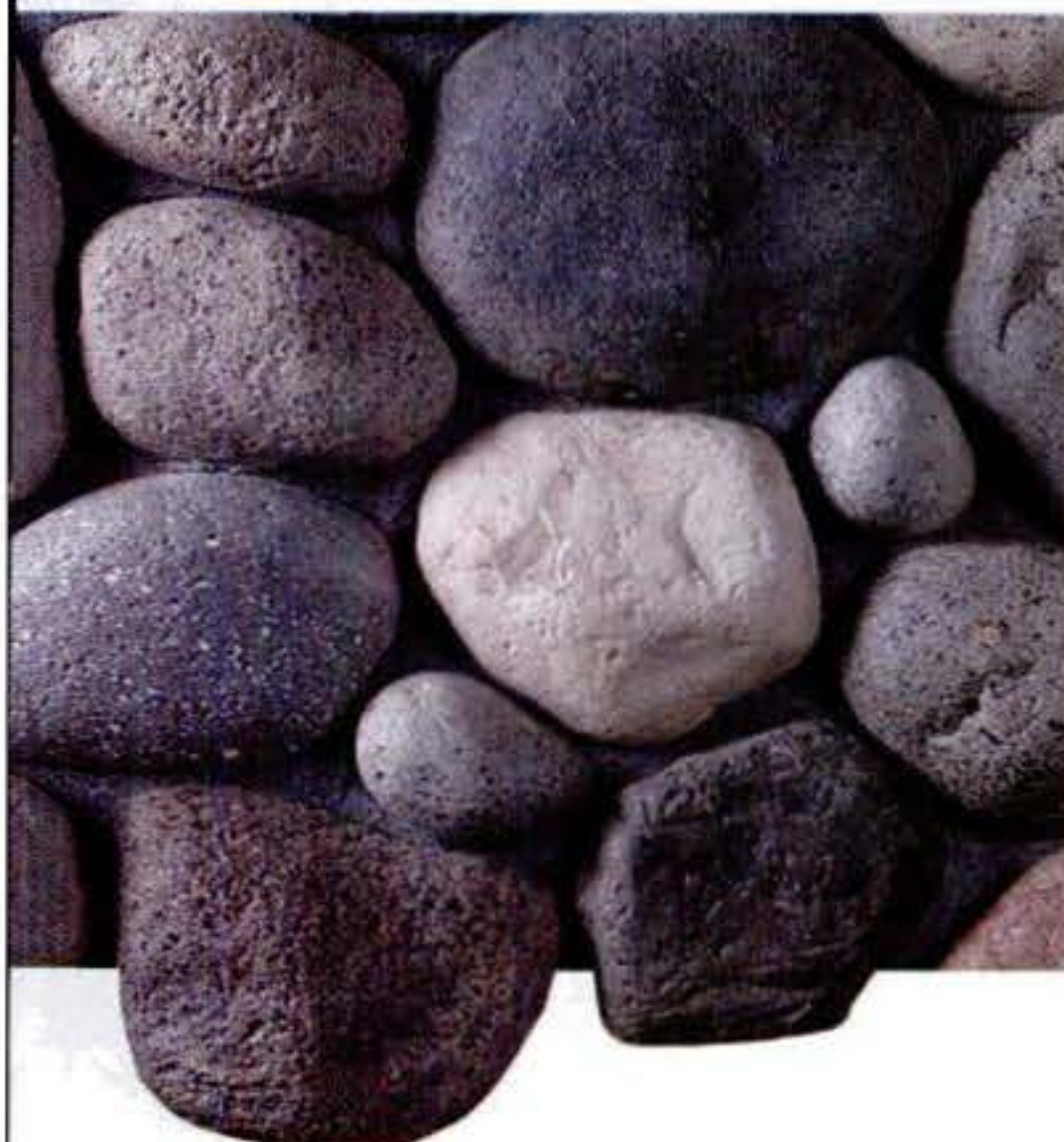


◀ Plug-in safety

Plug Shock Sentry into a two- or three-wire outlet, and you get ground-fault protection without any rewiring, says Eagle Electric Manufacturing Co. (45-31 Court Square, Long Island City, N.Y. 11101). The module is said to be able to detect an abnormal flow of current between the hot and neutral wires in a circuit and immediately cut power to its three outlets. Price: \$20.

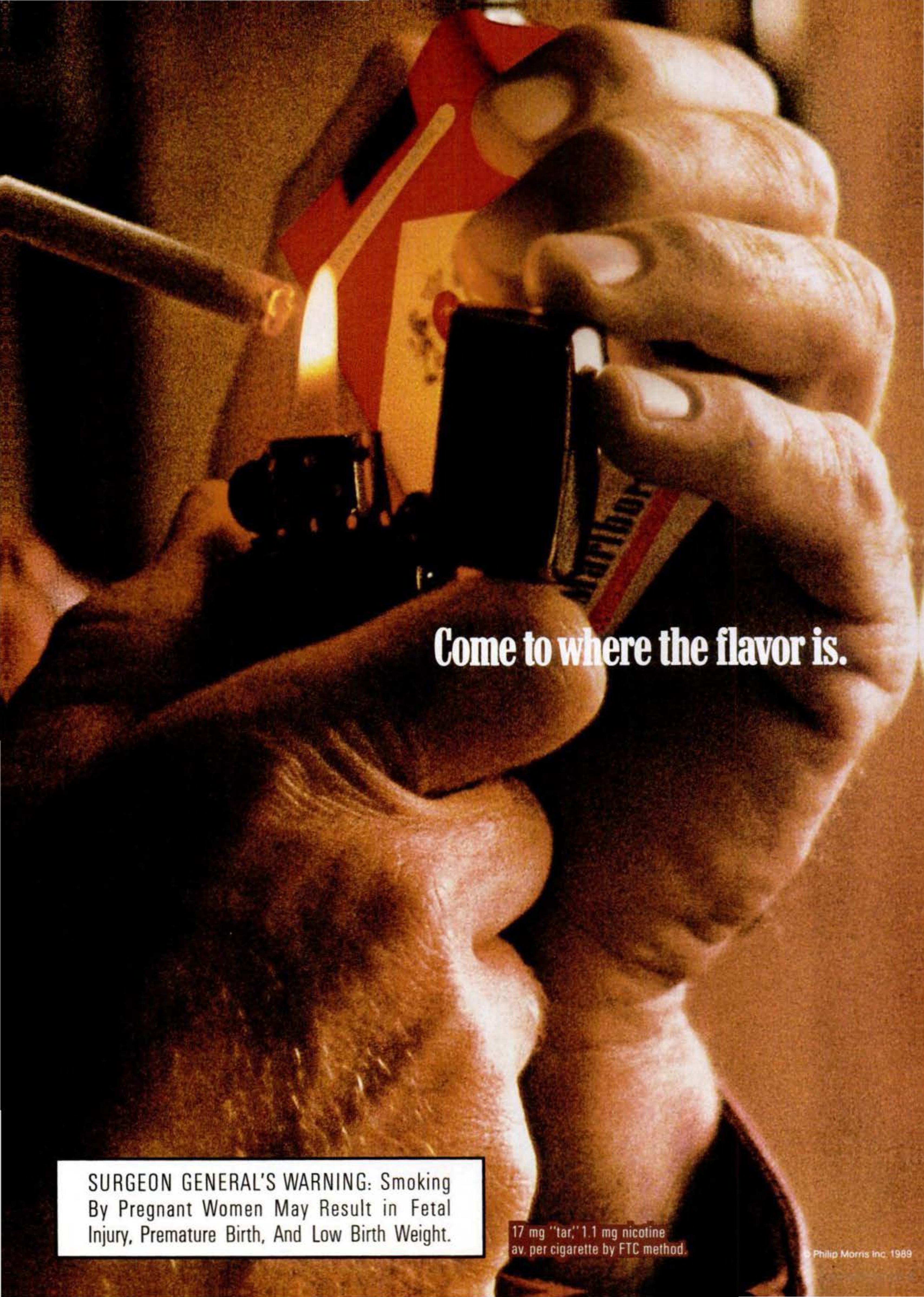
▼ New-tech molded sinks

What's different about this kitchen sink? It's made of Asterite, a dense polymeric dispersion that until this year was available only in Europe and Japan. According to the manufacturer, the acrylic material is stain-, chip-, and scorch-resistant—able to withstand temperatures up to 360 degrees F. Sinks from such companies as Spring Ram America (shown), Acriform International, Cambrian Collection, and Waltec Sinkware are made of Asterite. Manufacturer: ICI Americas Inc., Wilmington, Del. 19897.



Realistic river rock ▲

You'll have to look twice—or more—before you realize it's not real stone. Made of portland cement, mineral oxide colors, and special aggregate, this lightweight "rock" uses the latest in concrete mixing and molding technology, says Eldorado Stone Corp., Box 27, Carnation, Wash. 98014; \$2.75 a square foot.



Come to where the flavor is.

SURGEON GENERAL'S WARNING: Smoking By Pregnant Women May Result in Fetal Injury, Premature Birth, And Low Birth Weight.

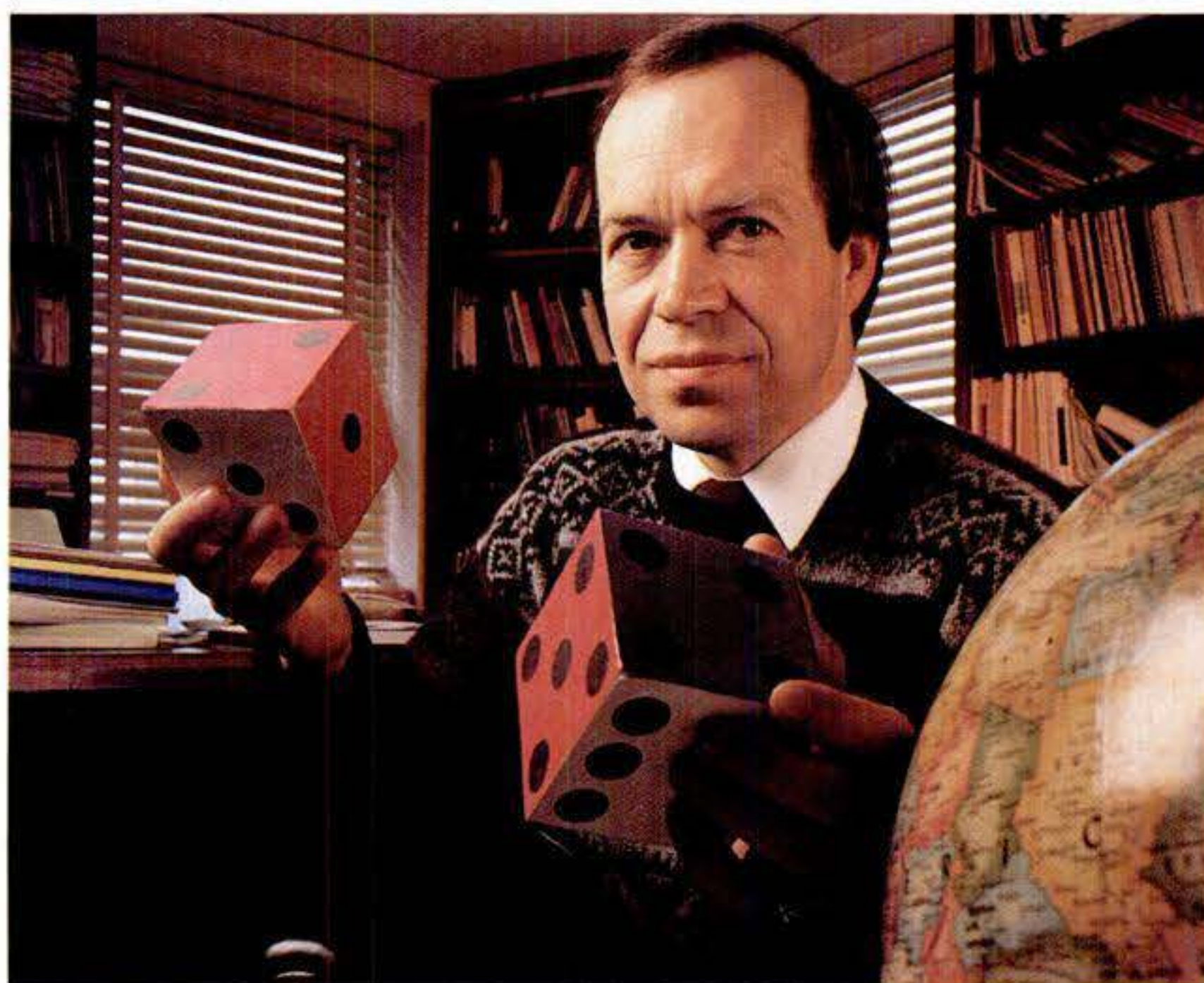
17 mg "tar," 1.1 mg nicotine
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GLOBAL WARMING

P A R T O N E

PLAYING DICE WITH EARTH'S CLIMATE



JOHN B. CARNETT

"We're loading the climate dice," says James E. Hansen. His testimony before a U.S. Senate committee last year capped more than 15 years of urgent warnings from climatologists who say mankind is altering Earth's heat balance by loading the atmosphere with increasing amounts of carbon dioxide and other gases. The result: global warming due to an accelerated greenhouse effect. Politicians are finally beginning to take notice, spurred in part by the deadly summer of '88. But has it taken too long to wake up to the problem?

Part I of this series goes to the experts to assess the nature of the threat. Is it real, or is the story just media hype? In coming months Part II will examine the little-told science behind the greenhouse effect. Part III will show what we can do to slow the change and prepare for the inevitable worldwide shifts in climate.

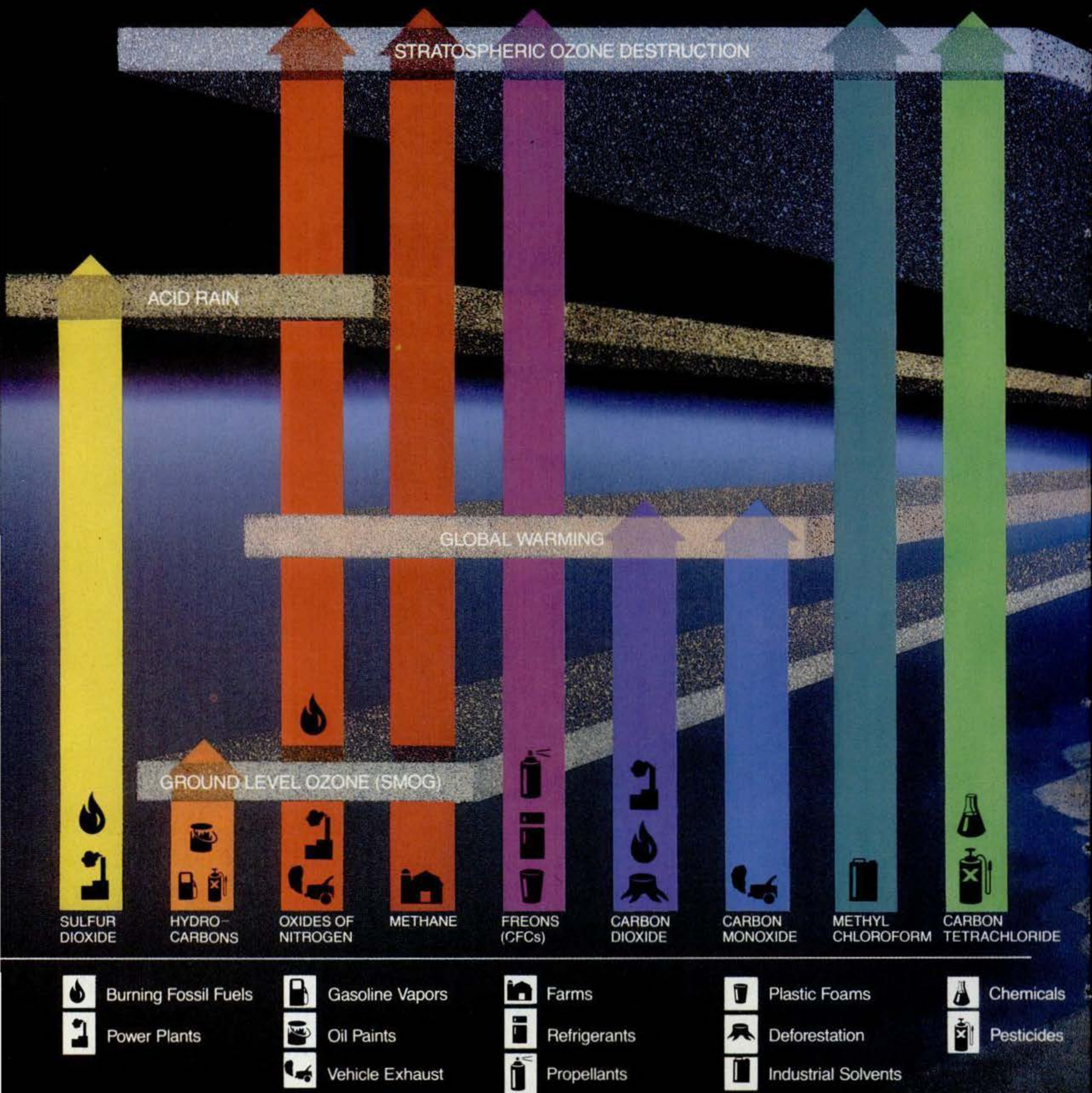
By **ARTHUR FISHER**

GLOBAL WARMING

ALL THE ILLS THAT EARTH IS HEIR TO

Global warming due to an accelerated greenhouse effect is arguably the most threatening of the environmental dangers—among them acid rain and the weakening of the protective ozone shield—that are directly linked to

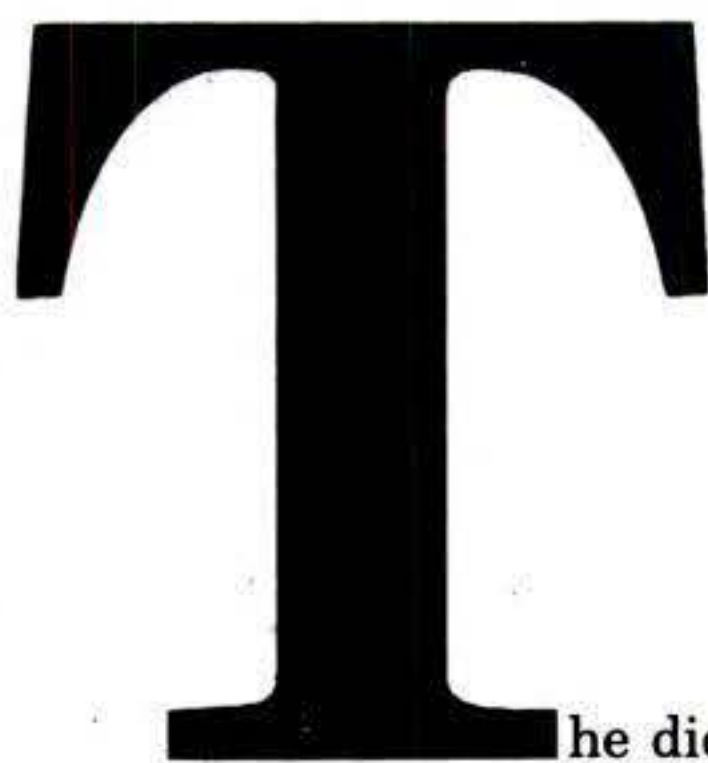
human activities. Ever since the beginning of the Industrial Revolution, advancing technology has spewed increasing amounts of polluting gases into the atmosphere, with the effects on the planet depicted here.



GLOBAL WARMING

Each pollutant is represented by a colored arrow. The negative results from the changes in atmospheric chemistry they cause are shown by their penetration of the flat gray arrows. One chemical may wreak havoc in more than one way. For example, chlorofluorocarbons contribute both to greenhouse-effect warming and to the destruction of the ozone layer in the stratosphere.

Of the so-called "greenhouse gases" that foster global warming, the most important to date is carbon dioxide, although methane and CFCs may come to rival its contribution. Principal human sources of carbon dioxide: burning of fossil fuels and deforestation.



The dice James E. Hansen keeps in his office are most peculiar. It's not just that they're big—maybe four inches on a side. They're also multicolored. One of them, he says, stands for Earth's climate from 1950 to 1980. Two of the die's faces are white, for an average summer; two sides are blue, for a colder-than-average summer; and two sides are red, for a hotter-than-average summer. Roll that die, and the odds on an average, a colder, or a hotter summer are equal—one in three.

But the other die, representing the climate he projects for the 1990s, has four red faces. Roll that die, and the odds on hotter-than-average summers double. We are not only playing dice with Earth's climate, he suggests, but the dice are loaded. The reason: Mankind is accelerating the greenhouse effect in a dozen complex ways, from the burning of fossil fuels to cattle ranching.

Hansen is the director of NASA's Goddard Institute for Space Science Studies, headquartered at Columbia University in New York City. It was his testimony before the Senate Energy and Natural Resources Committee one year ago that jolted both the political and scientific communities. Temperature records going back a hundred years, he said, have increased by about one degree F, and the warmest five years of that century have occurred in the 1980s. Hansen said that he was 99 percent certain the abnormally high global temperatures of the first five months of 1988 were due to human intervention producing an accumulation of greenhouse gases.

"It's time to stop waffling so much," he announced, "and say that the evidence is pretty strong that the greenhouse effect is here."

Hansen's remarks had all the more impact because they came in the midst of an ongoing spell of abnormal and sometimes devastating weather worldwide. The day that he spoke, June 23, 1988, the temperature in Washington, D.C., set a new record for the date—

99 degrees F. And the remainder of the summer left indelible mementos: drought, heat waves, floods (see box, 1988: A Summer to Remember).

When the year ended, the Goddard temperature data were confirmed and extended. In February scientists at the British Meteorological Office and the University of East Anglia's Climatic Research Unit reported that 1988 was the world's hottest year since reliable records began to be kept almost a hundred years ago. The East Anglia group, like Goddard, monitors world climate year by year. They use surface data gathered from thousands of international stations on land and on ships at sea.

Moreover, the British scientists said, the six hottest years of the century all fell in the decade of the 1980s. In descending order, they were 1988, 1987, 1983, 1981, 1980, and 1986. The average global temperature in 1988 was 0.612 degree F higher than the 1950 to 1979 average, which meteorologists use as a baseline for comparison.

Were the striking temperature patterns of the '80s and the tumultuous climatic events of 1988 in fact the result of greenhouse-induced global warming? Or were they, as one scientist joked, an "infrared herring?"

The answer is: A) It's impossible to tell with complete certainty, and B) It really doesn't matter. Whether it's responsible for a given summer or not, the greenhouse effect is a fact of Earth's life. Most scientists agree that continued global warming is inevitable and the implications are ominous.

Mankind seems to be faced with such an onslaught of environmental insults—acid rain, the ozone hole, toxic waste, deforestation, radon infiltration, desertification, pesticide runoff, radioactive residues—that a contemporary Chicken Little could not really be faulted for shouting "the sky is falling." Yet none of these threats compares with unchecked global warming in the potential for drastic and permanent impact on Earth and the life that thrives here.

The greenhouse effect is the phenomenon that keeps our planet warm because of the heat-trapping ability of certain atmospheric gases, notably carbon dioxide, methane, nitrous oxide, and chlorofluorocarbons. (These last are the same chemicals that are punishing the ozone layer.) The gases allow

Continued



GLOBAL WARMING

shorter-wavelength radiant energy from the sun to reach Earth's surface. But they block the longer-wavelength infrared radiation that the heated surface emits.

Francis P. Bretherton, a climatologist, is a former director of the National Center for Atmospheric Research (NCAR) in Boulder, Colo., a hotbed of research on weather and climate, past, present, and future. He is now director of the Space Sciences Center at the University of Wisconsin. Bretherton says that his fellow earth scientists foresee changes in climate and natural vegetation within the next 50 years as momentous as the total of all such changes that have taken place over the past 18,000 years—since the last Ice Age.

"We have just enough time left in this century," Bretherton says, "to understand the nature of our home, the Earth—to probe its history, to grasp the basic principles of its structure and operation, to gauge the impact of human societies on it, and to chart its future during the coming decades."

Earth's climate is far from stable. Climatic changes have resulted from a confounding interplay of forces: variations in the sun's energy output; continental breakups and collisions; volcanic eruptions; an evolving atmosphere being modified (from oxygen-poor to oxygen-rich, for example) by co-evolving life forms; even asteroid impacts.

Ice Ages seize the planet and then relinquish their grip in cycles determined by periodic changes in Earth's orbital motions—the Milankovitch cycles (see diagram).

For most of the past 600 million years, at least, Earth's climate has been milder than it is now. Fossils of ancient alligators from the Eocene, 50 million years ago, have been found in arctic regions. "The fossil evidence shows the polar regions were quite warm," says Eric Barron, director of Penn State's Earth System Science Center, "unless those alligators had fur."

During the Cretaceous period, some

100 million years ago, when dinosaurs dominated the land, Earth's climate was hot and steamy. Some researchers now believe that high levels of carbon dioxide in the Cretaceous atmosphere accounted for at least part of those conditions.

In our time, the level of carbon dioxide in the atmosphere has risen from 315 parts per million to 350 parts per million since 1958. Many experts be-

lieve that under the pressure of human activities it could zoom to 550 parts per million by the middle of the 21st century. And that alone, several computer models predict, would raise the global average temperature by some three to nine degrees F, with the extreme northern and southern latitudes experiencing more heating than the rest of the world.

That temperature increment might seem trivial. It is not. The average world temperature during the last Ice Age, when vast glaciers covered much of the Northern Hemisphere, was only eight degrees F lower than it is now. And during the so-called Little Ice Age, which lasted from 1450 to 1850, the difference was much less, perhaps as little as two degrees F. Yet the change was enough to make drastic alterations in both the climate and human culture: For example, grain no longer grew in Scandinavia.

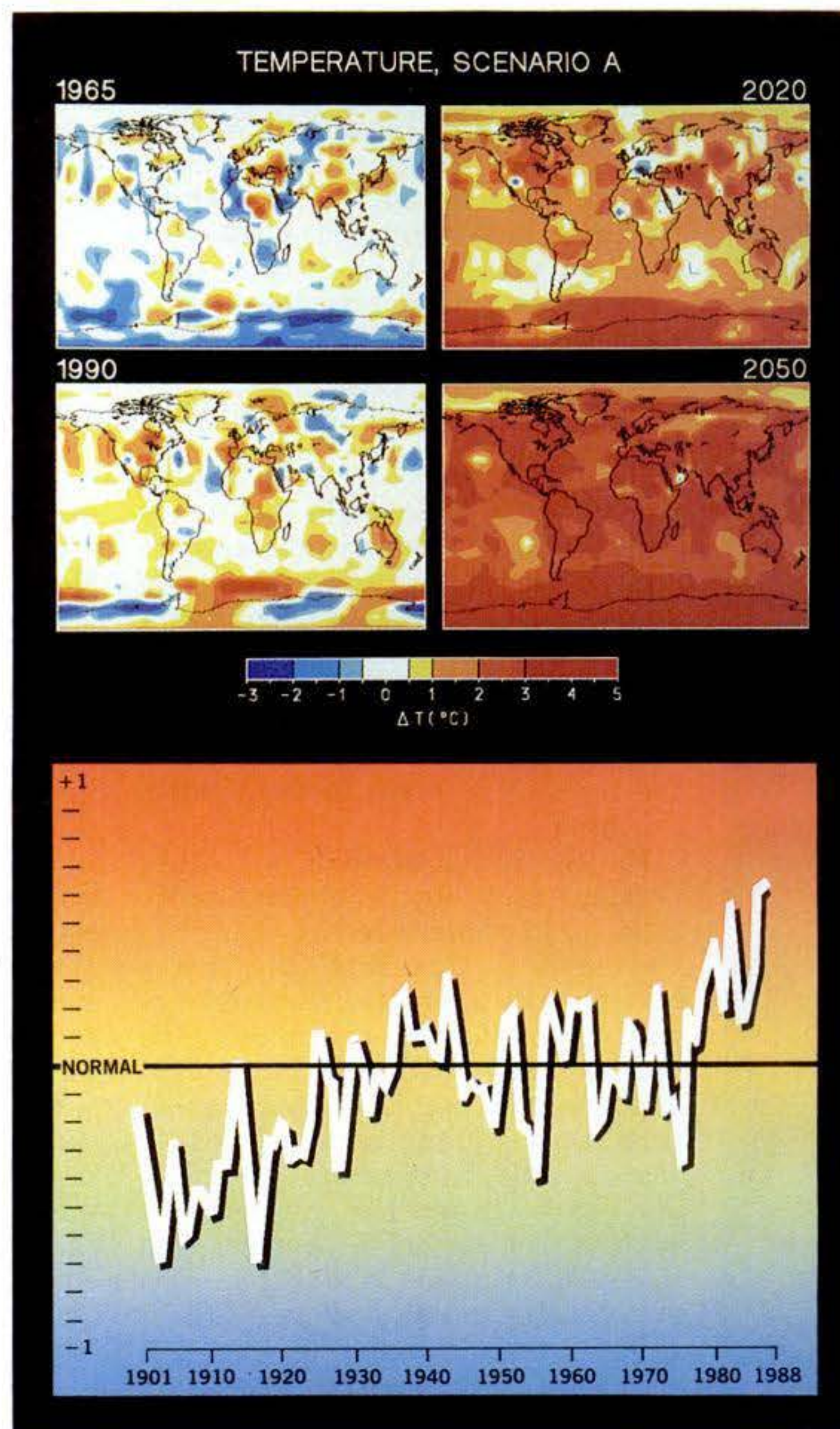
"Studies of past climate changes can tell us about what to expect as things heat up," says NCAR's John Firor. "We learn that even a slow change in climate can have dramatic effects if it continues long enough. As the last Ice Age retreated, the Earth warmed, slowly, for several thousand years. This change completely rearranged the face of America. Tree species that grew in Ohio and Michigan had to migrate far up into Canada to find a climate they could thrive in, and other kinds of trees from the deep South moved into Ohio and Michigan."

But Earth's atmosphere is being changed at an unprecedented rate, and the changes that most climate

modelers anticipate will occur at a pace far exceeding anything the planet has experienced in the past, as far as we can tell.

That's one of the things that most concerns Stephen Schneider, head of NCAR's Interdisciplinary Climate Systems Section.

"It's not the absolute magnitude of climate change that has me worried



Top: Climate model computer projections of global warming are based on NASA Goddard's Scenario A: 1½ percent increase in atmospheric carbon dioxide and three percent in CFCs per year, the current rate. James Hansen and colleagues call this "business as usual."

Bottom: Average global temperature has risen about one degree F since 1900. "Normal" baseline is the average temperature for 1950 to 1979.

SOURCE: NASA GODDARD INSTITUTE FOR SPACE

BOB LANGE

GLOBAL WARMING

so much," Schneider says, "it's the pace. If the world were to be warmed by five degrees in 250 years, certainly that would constitute a major change. For one thing, it might cause a rise in sea level. But 250 years is a fair amount of time for both humans and natural ecosystems to do some adjusting. If it's going to be five degrees warmer in fifty to one hundred years, however—that's just incredible. You don't adapt to that readily—it just hits."

The consequences of such a relatively sudden warming cannot be predicted with anything close to certainty. But the computer models of global climate at research centers like NCAR are churning out a range of possibilities, most of them fairly grim:

Sea-level rise could be the most devastating. (The term "sea level" means the average water level of the world's oceans, bays, tidal rivers, and estuaries over the period of one year.) It fluctuates over millions of years with the freezing and melting of ice—the eternal cycle of the Ice Ages.

At the height of a glacial period, much of the Northern Hemisphere is covered with sheets of ice thousands of feet thick. At such times, during the last two million years, sea level has been 300 to 500 feet lower than it is today. During warm interglacial periods much of the ice melts, and the sea level generally approximates what it is today. During the last interglacial, however, the level was some 20 feet higher than it is now.

Over the last 7,000 years, sea level has been gradually rising at a rate of an inch or two per century. But during the last century, as the global average temperature rose one degree F, the rise in sea level accelerated to between four and six inches. And that could be dwarfed in the relatively near future.

Thermal expansion alone (water expands when it is heated) could account for one or two feet of rise over the next 100 years. Melting of glaciers and ice-caps would add several more feet. Some climatologists are predicting a range of five to seven feet for sea-level rise over the next century. There is already some evidence from satellite data that polar sea ice has begun to shrink, according to studies at NASA and the U.S. Geological Survey (see satellite photo next page).

One imponderable is the stability of the West Antarctic ice sheet. Some polar experts have long fretted over the

danger of rising temperatures causing it to break off and collapse into the sea.

Doug MacAyeal, a geophysicist at the University of Chicago, has been developing a computer model to predict what might happen in the south polar region as a result of an increasing greenhouse effect, and expects to be able to make some accurate predictions on sea-level rise this summer. But it is possible, he says now, that Antarctic warm-

ing could be as much as 12 degrees F in the Antarctic 60 years from now. And that, he projects, would be enough to detach the West Antarctic sheet, with a resulting water-level rise of 20 feet.

Let's hope not. The far more conservative estimates of sea-level rise that most authorities project—say approximately five to seven feet—will be

Continued

1988: A SUMMER TO REMEMBER

- Record high temperatures spread across the United States. New York City suffers through more than 40 consecutive days of abnormal heat and humidity. Los Angeles reaches 110 degrees in September, when even relatively cool Seattle breaks 90. An estimated 10,000 "excess" deaths result from heat stress.

- In Moscow it is the hottest summer of the 20th century. Muscovites flee the city to cool off in any body of water they can reach, even polluted rivers and ponds. The number of experienced swimmers who drown is more than double the previous high for any summer.

- Widespread drought, reminiscent of the Dust Bowl days of the 1930s, results in 30 to 40-percent reductions in corn, soybean, and wheat production in the United States. Total loss: at least \$30 billion. A report by Stanley A. Changnon of the Midwest Climate Center and William Riebsame of the Natural Hazards Center ranks it as the nation's third worst drought of the 20th century. Says one 85-year-old Montana cattle rancher, staring grimly at his parched and barren acres: "I've been in this country since 1912. I've never seen it like this, not even in '34. My God, look at it. It's as bare as a dance floor."

- A combination of scorching heat and lack of rain plays havoc with water levels. Barges are stranded on the Mississippi as water levels on the Big Muddy sink. The result is major disruption in the shipment of bulk commodities such as grain, coal, and petroleum products. And along the shores of the Great Lakes, the water recedes so much that beaches 100 feet wide appear where there were none before. An incursion of salt water from the Gulf of Mexico threatens the drinking water supply of New Orleans.

- The high heat and stagnant air conditions generate unusually high levels of ozone in the lower atmosphere—the worst in a decade according to the EPA. The federal agency's health standard for the gas, which can irritate the eyes and the respiratory system, is 125 parts per billion. Anything higher than that signifies what the government terms "unhealthful conditions," under which people with breathing problems are urged to reduce physical activity. In the summer of '88, 76 cities register ozone levels at least 25 percent above that mark. In New York City the ozone level reaches 200 parts per billion on some days.

SOURCE: BRITISH METEOROLOGICAL OFFICE AND UNIVERSITY OF EAST ANGLIA



RICHARD WALKER/BRUCE COLEMAN, INC.

- Power outages plague electric utility systems in many parts of the country. On one superhot day in Los Angeles more than 400 electrical transformers blow up, overburdened by record demand as air conditioners surge on. A downtown area of Seattle endures a three-day blackout. Soaring electricity consumption in New England, the Middle Atlantic states, and the Midwest confront utility companies with demand not expected until the next decade and beyond. For them, it is already the 1990s. Even companies with apparently ample reserves of electrical generating capacity watch those reserves steadily evaporate.

- It is the worst summer for forest fires since 1919. Flames helped by the drought burn more than six million acres in the United States, a million in Yellowstone Park alone—that amount is half the preserve's total area. Some 2.2 million acres of tundra and spruce forest burn in Alaska—more than double the summer average.

- In late August Bangladesh is inundated by a massive flood that drowns almost 80 percent of its land. More than 25 million people lose their homes and are driven to wade through swirling polluted waters, with the inevitable result of cholera and dysentery epidemics. More than 1,200 people are killed outright. Bangladesh used to be savaged by such monsters about once in 50 years. But since 1980 there have been five "50-year" floods, each more punishing than the last.—A. F.

GLOBAL WARMING

indeed difficult enough to deal with.

"Don't buy land in New Orleans," says John Milliman of the Woods Hole Oceanographic Institution. Low-lying cities like the Big Easy and Miami would be inundated by a three-foot rise, which some predict by 2050. U.S. cities on the East and Gulf Coasts are especially vulnerable, because much of those coastlines are sinking six to eight inches a century.

The U.S. Environmental Protection Agency estimates that a six-foot sea-level rise would destroy as much as 80 percent of this country's coastal wetlands, which are vitally important to the nurturing of fish and shellfish populations. A mere one-foot rise will erode 100 to 200 feet of beach front, wiping out many barrier-island communities that have built condos and hotels close to the ocean. With a rise of five feet, the EPA states, areas in Charleston, S.C., that are now flooded once in a century by storm surges will be flooded every 10 years.

Major cities the world over will face similar problems—Bangkok and Venice are obvious examples.

If by 2050 the Florida Keys "will no longer exist," in the words of Elton J. Gissendanner, past executive director of the Florida Department of Natural Resources, then around the world entire nations may face major disruption or even near or total extinction. One of them is Bangladesh, 80 percent of which is a vast river delta. John Milliman sees a worst case scenario for Bangladesh in which 38 million of its inhabitants will be forced to relocate by 2100. By 2100 in Egypt, up to 26 percent of habitable land could be under water.

As for the Maldives, a tiny island nation made up of some 1,200 atolls with a maximum height of six feet—they will simply disappear under a seven-foot rise. And a storm surge after even a three-foot rise, says Maldivian President Maumoon Abdul Gayoom, would be "catastrophic and possibly fatal."

Even the probability of hurricanes and other major storms will be enhanced by global warming, some climatologists predict. At the Climate Institute's Second North American Conference on Preparing for Climate Change last December, James E. Hansen said that a model of the effects of warming on the oceans showed that increased evaporation would generate more vigorous convective currents in

the atmosphere. The result: storms 40 to 50 percent more energetic than present ones, with monster hurricanes hurling winds of 225 mph.

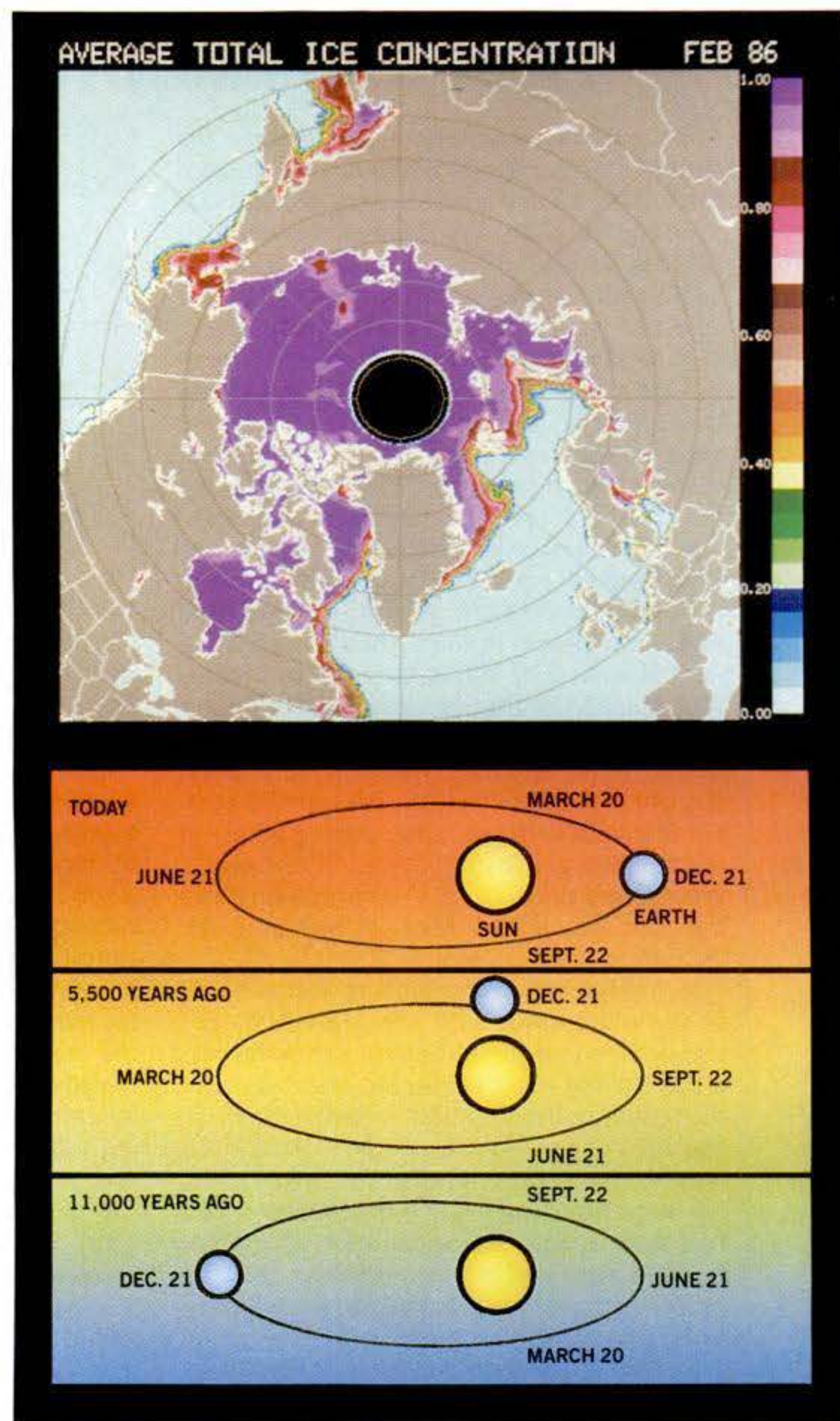
Ironically, with all this extra water will come more dry periods in some regions. By 2030, Hansen said, the odds for severe summer droughts in the middle and lower latitudes of Earth would rise to one in three, in contrast to the 1 in 20 odds characteristic of the 1950s.

An EPA report prepared for Congress to assess possible impacts on four regions of the United States—California, the southern Great Plains, the Great Lakes, and the Southeast—forecast major changes in our forests. In central Michigan, for example, sugar maple and oak trees could be replaced by grasslands. A University of California at Santa Barbara study suggests that an increasingly dry and warm climate will nudge forests in eastern North America gradually northward. Spruce, pine, and fir trees will abandon the upper Midwest for Canada. The head of the UCSB study, Daniel B. Botkin, reported to the American Association for the Advancement of Science last January that "If the climate warms as rapidly as currently predicted, there will be visible and dramatic changes in U.S. forests within most of our lifetimes."

Heat waves? Of course. Stephen Schneider uses the loaded-dice analogy that Hansen does, but with many more faces. "Let's think of a summer's climate as being the result of a roll of a pair of dice by nature," he says. "And let's assume there are 1,200 faces

instead of twelve: warm ones, cool ones, wet ones, dry ones, and so on. If the world is going to warm up—and warm up rather suddenly and drastically, as most scientists believe—then that will have the effect of erasing some of the cooler faces and replacing them with hotter ones. And we also may be replacing wetter faces with drier ones, according to some projections."

The result of loading the dice, Schnei-



Top: Nimbus 5 and 7 satellite images of polar sea ice over a 15-year period show a significant decline of six percent in maximum global sea-ice extent, corresponding to the world's average temperature rise during that time.

Bottom: Periodic variations in Earth's orbit and axial tilt, known as the Milankovich cycle, result in the slow shift of the equinox and solstice. One complete cycle takes 22,000 years. It is linked to the periodicity of the Ice Ages.

GLOBAL WARMING

der says, can be put in terms of the probability of heat waves: For example, the odds of getting five or more days in a row with maximum temperatures above 95 degrees in Washington, D.C., are now about one in six. If the average global temperature goes up three degrees F, the odds rise to nearly one in two. And in Dallas, the odds of five or more days of 100-plus heat in July go from one in three to two in three. The dictum for the next century, one expert suggests, might be, "If you can't stand the heat, get out of Saskatchewan."

Schneider has been sounding the tocsin about the greenhouse effect and global warming for the last 16 years, much of the time to polite yawns. Now, ever since the spring of 1988, he and many of his colleagues have received the respectful attention of politicians and planners, and been near canonized by the media.

"It's like applying to college," Schneider says. "The worst of all worlds is not to get any offers. The second worst is to be accepted by all six."

"I like the dice metaphor," he says, "because it says that in any one case of nature rolling the dice, such as the U.S. climate anomaly of 1988, it's impossible to know definitely whether it is a random, extreme fluctuation or evidence that we have loaded the dice."

In fact, one of Schneider's colleagues at NCAR, Kevin Trenberth, has theorized that the Midwest's drought of 1988 was specifically linked to a naturally occurring cycle of water-temperature changes in the equatorial Pacific Ocean.

Periodically, an abnormally warm stretch of surface water appears in this region and upsets weather patterns around the world—causing rain in the bone-dry Atacama Desert of South America, for example. The phenomenon is called El Niño, or little boy, by association with the Christ child; it often occurs around Christmastime.

Recently, climatologists learned that El Niño is actually part of a cycle, alternating with periods of abnormally cold equatorial Pacific water, a phenomenon they have dubbed variously La Niña (little girl), El Viejo (the old one), or just plain "cold cycle." It was an unusually severe cold cycle, Trenberth believes, that shoved the jet stream far north of its usual spring and summer path, so that rain-bringing thunderstorms were steered across

Canada rather than the Midwest.

Even if this theory proves to be correct, Schneider says, the greenhouse effect and subsequent global warming could tilt the balance, making cold-cycle droughts and heat waves more severe than they would otherwise be. "And no, we can't pin one hot summer on the greenhouse effect. If you roll snake eyes three times in a row, is it just bad luck or does it prove the dice

this possibly unconnected event has brought us to the right level of consciousness about the problem, a level that should have been reached about fifteen years ago. The point is that there is no controversy—none—about the existence of the greenhouse effect. It's the best established theory in the atmospheric sciences."

As evidence, there is the Goldilocks phenomenon: the wildly differing con-

PHOTO: ICE AND CLIMATE PROJECT, UNIVERSITY OF PUGET SOUND



Massive sheets of ice like this Bering glacier would contribute to sea-level rise as the temperature rose. Ice covered much of North America during the last Ice Age.

are loaded?" But Schneider thinks the rise in global average temperature over the past century and the record heat of the 1980s are persuasive.

When the East Anglia University's Climatic Research Unit confirmed that 1988 was indeed the hottest year of the century, the British experts took a fairly neutral position. David Parker of the British Meteorological Office said that although the observed heating was "consistent with the greenhouse effect caused by the rise of carbon dioxide and other man-made gases in the atmosphere... the Earth's temperature fluctuates considerably due to natural causes, and no unambiguous connection can yet be made." Nevertheless, he noted, not all of the record-breaking warmth of 1988 could be accounted for by such a random variation.

"The irony," says Schneider, "is that

conditions on three neighbor planets: Mars, Venus, and Earth. The atmosphere of Mars is about 95 percent carbon dioxide, but it is exceedingly tenuous, more than 100 times thinner than Earth's. So little of the sun's heat is trapped by the atmosphere that the planet is colder than a deep freezer. Winter at the Martian poles brings temperatures of minus 180 degrees F. That's too cold for life.

Venus lies at the other end of the gamut. Its atmosphere, 97 percent carbon dioxide, is very thick. The pressure at the Venusian surface is 90 times Earth's. As a result, Venus has been called a "runaway greenhouse." If Mars is like a deep freezer, Venus basks in the temperature of a self-cleaning oven, about 900 degrees F—too hot for life.

"Now," says Schneider, "look at the

Continued

GLOBAL WARMING

Earth, that lovely blue ball with its envelope of clouds and liquid water on its surface. The composition of its atmosphere gives just the needed greenhouse effect. Not too cold, not too hot, Earth is just right—like the porridge Goldilocks finally ate.

"So the greenhouse effect explains the climates of the three planets. It explains why Earth is equable for life. The only controversy is whether small increments in the contents of the greenhouse gas envelope of Earth will make the climate one or five degrees warmer, whether a given increase is going to take twenty years or 120 years, whether it's going to get drier in Iowa or hotter in India—and ultimately, what to do about it."

The reason for large uncertainties in pinning down both the time scale and the precise nature of climate changes for specific regions of the world is that global climate models are not refined enough, and the computers they run on are not powerful enough, to cope with the hideous complexities of the problem. Nor have researchers been acquiring enough data, especially from the oceans, to fine tune the models, which now can only give crude approximations of a monstrously complex global system.

"We are working," says Schneider, "with some pretty cloudy crystal balls."

Cloudy or not, the climate models and most modelers agree on the overall impact of the greenhouse effect. There is no way to reverse the effects of adding greenhouse gases to the atmosphere. But there are ways to slow the pace of atmospheric change, including changes in the way society generates and expends energy. Last February, for example, an international conference on global warming held in India recommended a tax on gasoline and other fossil fuels in Western countries, which are the major users of non-renewable energy resources.

Controlling the rampant destruction of tropical forests in the Third World to provide grazing land for cattle would also be helpful: That practice spews carbon dioxide into the atmosphere when the trees are burned; eliminates the re-

moval of carbon dioxide from the atmosphere by those self-same trees; and multiplies the generation of methane (in the digestive systems of cows). The other side of that coin is to plant more trees—lots more. (These issues will be discussed in Parts II and III of this series.)

U.S. lawmakers have already begun to press for some remedial measures. In February a bill entitled "Global Warming Prevention Act of 1989" was introduced in the House of Representatives by Claudine Schneider and 50 cosigners. It was similar in many ways to earlier bills proposed by Senators Timothy Wirth and Albert Gore, calling for, among other things, a 20-percent cut in carbon dioxide concentrations by the year 2000, elimination of CFC production within five to seven years, tax incentives for fuel-efficient cars, hundreds of millions of research dollars for renewable energy resources, and increased U.S. support for family planning services in Third World countries.

Whatever the options, there is a growing sense of urgency about doing something now, not waiting for another 10 years or so for "concrete proof" that we may be wreaking irreparable harm on our planet.

"There's not going to be a bell that rings and announces 'greenhouse detected,'" says Schneider.

One sample of the growing consensus came from a major international conference held in July 1988 in Toronto called "The Changing Atmosphere: Implications for Global Security."

Its closing statement read, in part: "Humanity is conducting an unintended, globally pervasive experiment whose ultimate consequences could be second only to a global nuclear war. The Earth's atmosphere is being changed at an unprecedented rate by pollutants resulting from human activities, inefficient and wasteful use of fossil fuels, and the effects of rapid population growth in many regions. These changes represent a major threat."

This May, another international gathering of government officials, scientists, and industry representatives—called the "Forum on Global Change and Our Common Future"—was held in Washington, D.C. It was sponsored by the National Academy of Sciences, Smithsonian Institution, the American Association for the Advancement of Science, and Sigma Xi. In a keynote address, Norway's Prime Minister, Gro Harlem Brundtland, said, "The threats to the global climate prove that if everyone does as he pleases in the

short run, we will all be losers in the long run. We need to develop a more global mentality in charting a course toward the future, and we need sound scientific advice and firm political and institutional leadership."

And in a poignant letter last August to the British journal *Nature*, F. Kenneth Hare, chairman of the Climatic Planning Board of Canada, warned that there will never be proof absolute enough to persuade every doubter that a buildup of greenhouse gases is directly responsible for global warming. But as a scientist and adviser to his government, he wrote, "I can and do tell them that they should base their environmental planning on the assumption that the greenhouse warming will continue and accelerate. There will always be conservatives who decline to go this far. At the age of sixty-nine I can no longer afford to be conservative."



MALCOLM WELLS

Researchers are refining a super-sensitive radar device that can detect heart and breathing movements. Possible uses include locating earthquake or avalanche victims, finding terrorists or fugitives, and pinpointing battlefield wounded.

I'm sitting behind a red-brick wall in a Michigan State University laboratory in East Lansing. A breadbox-size radar system beams weak microwave energy at me through the bricks. "Hold your breath," electrical engineering professor Kun-Mu Chen tells me. "Now breathe normally again," he says seconds later, so that his instruments will capture different readings.

Then Chen shows me the results—spiked waveforms on graph paper. "Here's your breathing and heartbeat," he says, pointing to a tall string of spikes. "And here's just your heartbeat," says Chen, indicating smaller waveforms.

Chen's life-detection system, developed with his students, uses ordinary low-power radar transmitter-receivers. Radar echoes from a person's skin surface are phase shifted (changed compared to a reference oscillator signal) by breathing vibrations or heartbeats. This modulation of the radar signal is displayed as periodic waveforms. Detectors use frequencies in the gigahertz (billion-cycle) range. "In experiments at ten gigahertz," Chen says, "we've been able to detect persons as far as three hundred feet away." At that radar frequency, detectors might help medics to locate battlefield wounded, or nurses to monitor the breathing and heartbeats of hospital patients without having to enter their rooms.

Life detectors operating at two gigahertz could help rescue earthquake survivors beneath five feet of rubble. Radar sensors would also let police spot a fugitive hiding in a warehouse or a terrorist behind even the thickest walls.

More research is needed. Current laboratory equipment, for one thing, is *too* sensitive. When some of my life readings seem erratic, Chen explains, "there must be somebody over in the neighboring lab. We're picking up his life signals too." Chen and his colleagues are improving detectors so they'll pick up fewer of these so-called "garbage" echoes. "All we need is a better antenna," he says. Right now, the ultra-sensitive radar might detect life functions of dogs, cats, spiders—even the nodding of a grass blade—says Chen, "whether you want them measured or not." PS

In this artist's concept, a portable life detector locates building-collapse victims by beaming radar through the rubble. Echoes displayed on a screen have a rhythmic pattern, indicating that someone is alive.

LIFE DETECTOR

By GODE DAVIS

ILLUSTRATION BY WILLIAM HOSNER



An extraordinary vessel uses twin outer hulls, a semi-submerged main hull, and active bow planes for unusual stability. Innovative drag-reduction and propulsion technologies promise high fuel efficiency and extended range. The 104-foot prototype, slated for a fall launching, could herald a new shape for ocean liners and military vessels in the 1990s.

TRI-HULL SHIP

At the Peacock Boatyard in Wilmington, Calif., people line up in cars to stare at an odd-looking vessel. "They're building her to research storm systems off the Cape of Good Hope," goes one rumor. The ship, with three side-by-side hulls, a long bulbous nose, and an unusual cylindrical stern, is a radical departure from conventional ship design.

Some design principles used in this novel craft come from jet aircraft engines. Others, also new to the maritime world, are used to reduce drag, boost fuel efficiency, and smooth the ride through rough seas. If this prototype design is applied to aircraft carriers, battle cruisers, and container and cruise ships, it could revolutionize ship building.

The strange vessel is the brainchild of 74-year-old inventor and businessman Calvin Gongwer, who came up with the initial idea about 20 years ago. "I'm a hydrodynamicist/power-plant type," he explains. "I've been around so long I eventually got ideas how to put a package together that would be better than conventional ships." Gongwer financed the striking vessel—some \$250,000 annually for the past eight years—with funds from his small marine-propulsion company, Innerspace Corp., in Covina, Calif. He named the ship *S.S.T. Theodore von Karman* after his teacher and friend, the aeronautics pioneer who died in 1962. (SST stands for Semi-Submerged Trimaran.)

Gongwer's build-it-yourself project demanded ingenuity. As he created small models, for example, his 42-by-18-foot backyard swimming pool became a research test basin. "Refraction of sunlight through the smooth water surface showed distinct wave-pattern shadows on the pool bottom," Gongwer explains. "Some of them are beautiful." He analyzed the patterns on countless photographs. Gongwer

By **ANTHONY L. CARONE**
and **JOHN FREE**
Photos by Ken Rogers

also studied the movements of yarn tufts attached to the hulls. Finally he perfected a 36-inch-long motorized model with minimum drag.

Work on the full-size prototype began eight years ago. The triple hulls, with a 17-foot bulbous bow on the center hull, work together to stabilize the vessel against roll, pitch, and heave. The twin outer hulls, or sponsons, ride on the water, acting as outriggers, while the main hull, built eight feet lower, is deep in the water.

Built into the tip of the bow for maximum effect is another stability aid: active bow planes. Initially, they'll be adjusted manually through hydraulically actuated cables to minimize pitching. Bow planes will be set "from the feel and inspection of oncoming seas," says Gongwer. Later, gyros will automatically trim the planes.

That's not all. On a vessel brimming with innovation, the bow planes have another role. This one emerged in the mid-1960s when Gongwer invented a super-efficient swimming aid called the Aqueon. This spring-loaded device, shaped somewhat like a model airplane glider, is actuated by kicking both legs. To demonstrate it, Gongwer raced—and beat—younger Navy frogmen. Once he swam 25 miles to Santa Catalina Island, towing a lifeguard. "These bow planes are a direct scale-up of the Aqueon blades, which are superbly propulsive," Gongwer says.

"So in a pitching sea, a small amount of propulsion will come from them."

In addition to stabilization, the hulls and bulbous bow are designed to reduce drag in a unique way. Gongwer, who studied aeronautics for his master's degree, draws an analogy between the vessel's 17-foot bow probe and long cones installed in front of some supersonic jet engines. These cones generate a shock wave captured by the jet engine intakes to boost compressor efficiency.

On his trimaran ship the submerged hull probe produces a V-shaped wave train that interacts with waves from the thicker main-hull bow (see diagram). Both sponsons capture the shock waves from the main hull and long bow. Ideally, when they mix, one wave is cresting while the other is in a trough. "It means we're cancelling some of the energy that would ordinarily be dissipated in the wave train of the ship," Gongwer says.

A computer study at the U.S. Navy's David Taylor model basin in Bethesda, Md., suggested that rear extensions to the sponsons—up to 16 feet long—should enhance the effect. These extensions, being added at this writing, can be adjusted laterally and vertically. "We're going to adjust them until we get the lowest drag," says Gongwer.

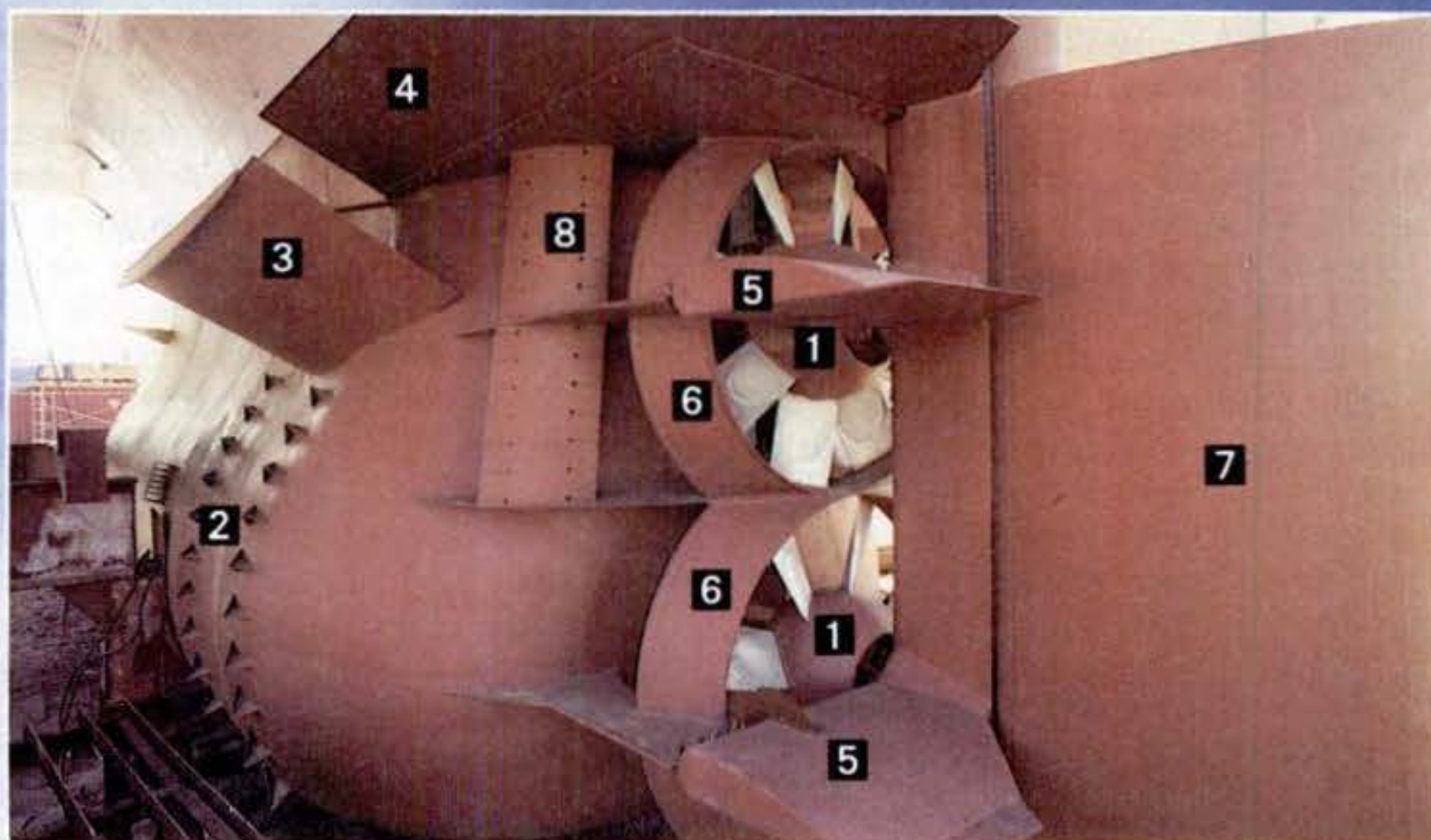
Actuator disc propulsion

The vessel's stern section is also unusually complex. Instead of tapering into the water, the stern afterbody is nearly hemispherical. Most stern components—planes, plates, and nozzles, for example—are designed to maximize thrust.

Naturally the propellers are special too. The props are Gongwer's patented actuator discs: Each has eight thin blades designed to turn at up to 275 rpm—about one-third the speed of conventional propellers. They'll each de-

Continued

A bulbous bow for the triple-hull ship (below) is designed to create a wave train that aids in drag reduction. A metal plate will seal the cone-shaped opening formed by the bow-nose halves. Front bow planes can be adjusted to minimize pitching of the ship. The complex stern section (right) has a rounded base and other components to boost thrust from the propellers, called actuator discs **1**. Turbulators **2** are small projections to help smooth the flow of water around the curved stern section. Stern planes **3** help force water over the propellers and, along with an anti-aeration plate, **4** minimize air mixing with the water. Other stern planes **5** are foil shaped for lift. Nozzles **6** help direct water in the propellers. A conventional rudder **7** steers the ship. Baffles **8** aid reversing.



liver 8,000 to 10,000 pounds of thrust by sucking water smoothly around the stern's elliptical surface. Gongwer, incidentally, also used an actuator disc on his two-person human-powered sub slated to race in Florida last June ["Muscle Subs," June].

Four diesel engines, totaling about 1,100 horsepower, spin the props. The Caterpillar engines are stacked two above and two below in the engine room. Prop shafts are 6.7 feet long and linked to the engines by drive belts, another noteworthy Gongwer touch.

Gongwer's vessel, built under U.S.

Coast Guard supervision, can weather the roughest seas. "A torsion box girder was installed to link the three hulls in a rigid way," he says. This powerful structure, also used for aircraft wing spars, rests on the main deck and is welded to the main hull and sponsons. The 7-by-33-by-45-foot box is topped by the pilot house and contains the crew quarters, galley, and other compartments.

The ship is slated for launching this fall. "We don't expect to realize our full eighteen-knot speed until we have about six months of playing around and tweaking things," says Gongwer.

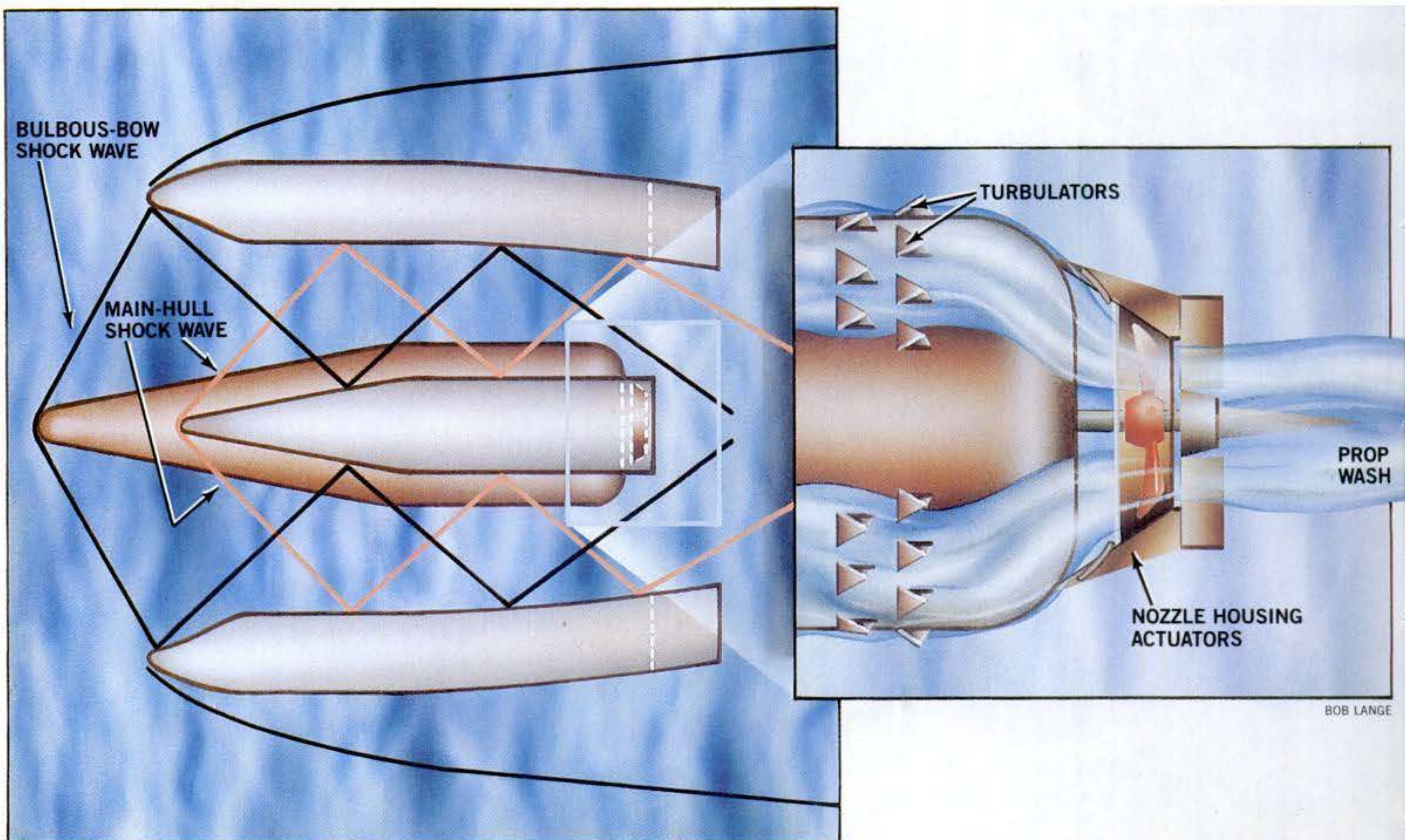
Underwater observation ports in both sponsons will let him view water flow, eddies, and wave patterns by inspecting lengths of test yarn. A diver will then adjust components.

At just over 10 knots, a more common hull speed, Gongwer estimates the vessel's 13,500 gallons of fuel could take it from Los Angeles to Australia and back to Hawaii. The veteran researcher is already eyeing the 72-percent boost in speed possible with, say, a 300-foot vessel: "If I had my druthers," he says, "I'd be laying the hull for a big cruise ship." **PS**

Shock waves created by the vessel's submerged bulbous bow and main hull are damped by deflecting both of the wave trains at opposite angles between the sponsons (outer hulls) and main hull. Ideally, the waves cancel each other. Sponson sterns are bent inward slightly to optimize this complex wave pattern between the hulls. Small protruding pyramidlike projections, called turbulators, force water around the vessel's blunt stern into nozzles covering the propellers (below right). Designer Gongwer, right, demonstrates how these double rows of offset turbulators deliberately disrupt water flow over the stern. Directing water through the propellers this way increases thrust and efficiency. Propellers operate in the wake of the vessel.

FROM SINGING PROPELLERS TO A TRIMARAN

Calvin Gongwer's half-century career as a hydrodynamics research engineer began with a mechanical engineering degree from Columbia University in 1937 followed by a master's in aeronautical engineering from the California Institute of Technology. Gongwer's Innerspace Corp., formed in 1963, produces underwater motors and his patented thrusters used by the U.S. Navy, oil companies, and other organizations for undersea work and exploration. A paper Gongwer authored 37 years ago solved the problem of singing propellers, which once disclosed submarine positions. He has since received 70 patents and a number of awards, including the American Society of Mechanical Engineers' 1983 Henry R. Worthington medal for work that solved design problems of cavitation and stall in centrifugal impellers. This formed the basis for much of the current design and study of centrifugal fans, pumps, and propulsion systems. —A.L.C. & J.F.



BOB LANGE

Synthetic slate that looks and performs like the real thing, exteriors that look like stucco but insulate from the *outside*, bendable lumber, sound-proof wood floors. Many innovations in materials and technology find their way into the home—in new building and home-improvement products. Here is a collection of some of the most interesting and innovative products for improving your house—from roof to basement.



TECHNOLOGY COMES HOME

By TIMOTHY O. BAKKE
Drawings by Mario Ferro

ROOFING

If I hadn't known better, I would have been fooled. Other staff members *were* fooled when I showed them the samples and asked, "What do you think this is?" They all answered, "Looks like roofing slate."

It was, but it wasn't. Bill Morrissey, director of marketing for Eternit Inc., had sent me samples of the company's fiber-cement roofing. It mimics natural slate and offers similar long-lasting performance, but costs and weighs less. The Eternit slates are just one of a burgeoning category of modern roofing products made with surprising new materials. A new Mediterranean-style roofing tile—like

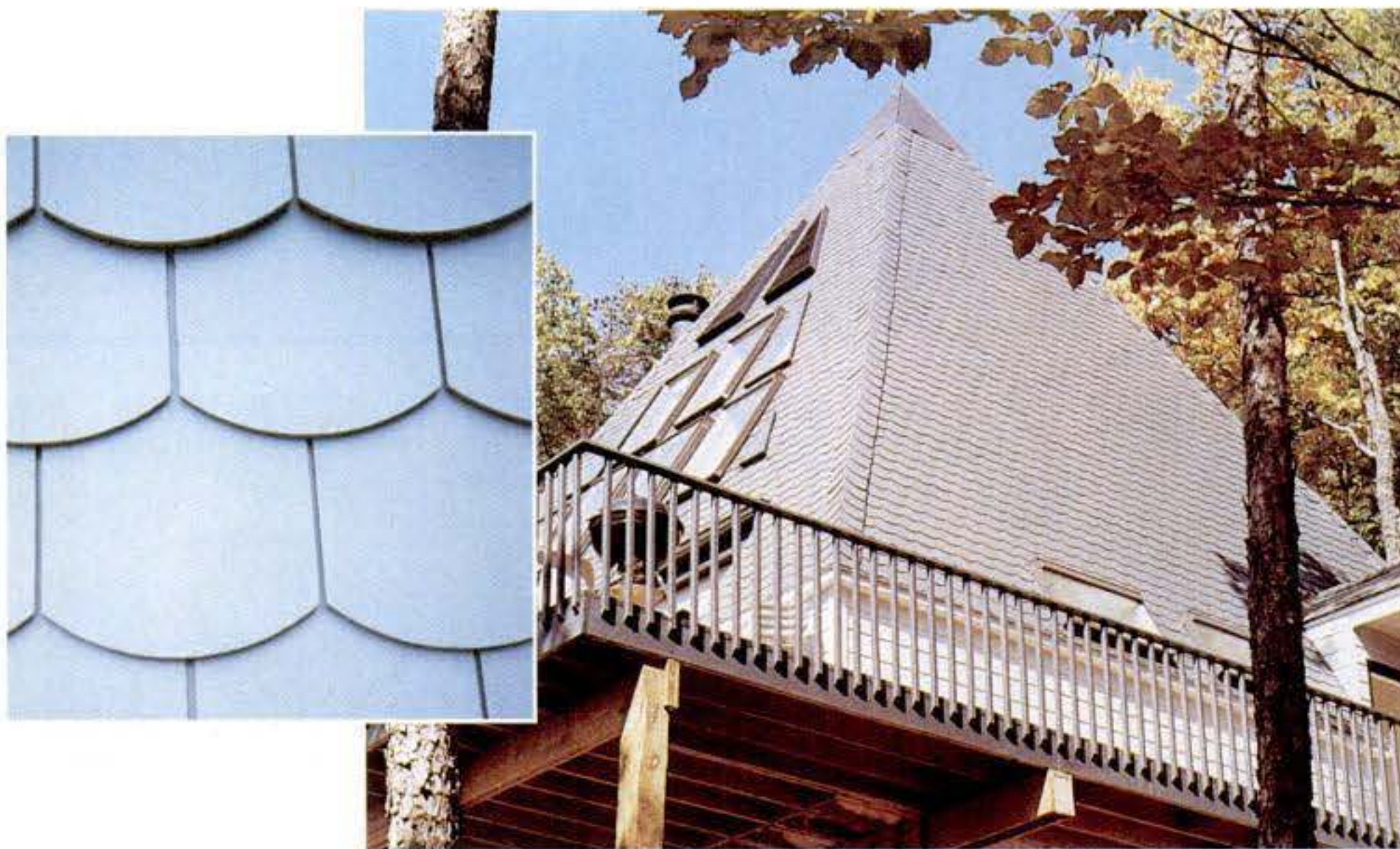
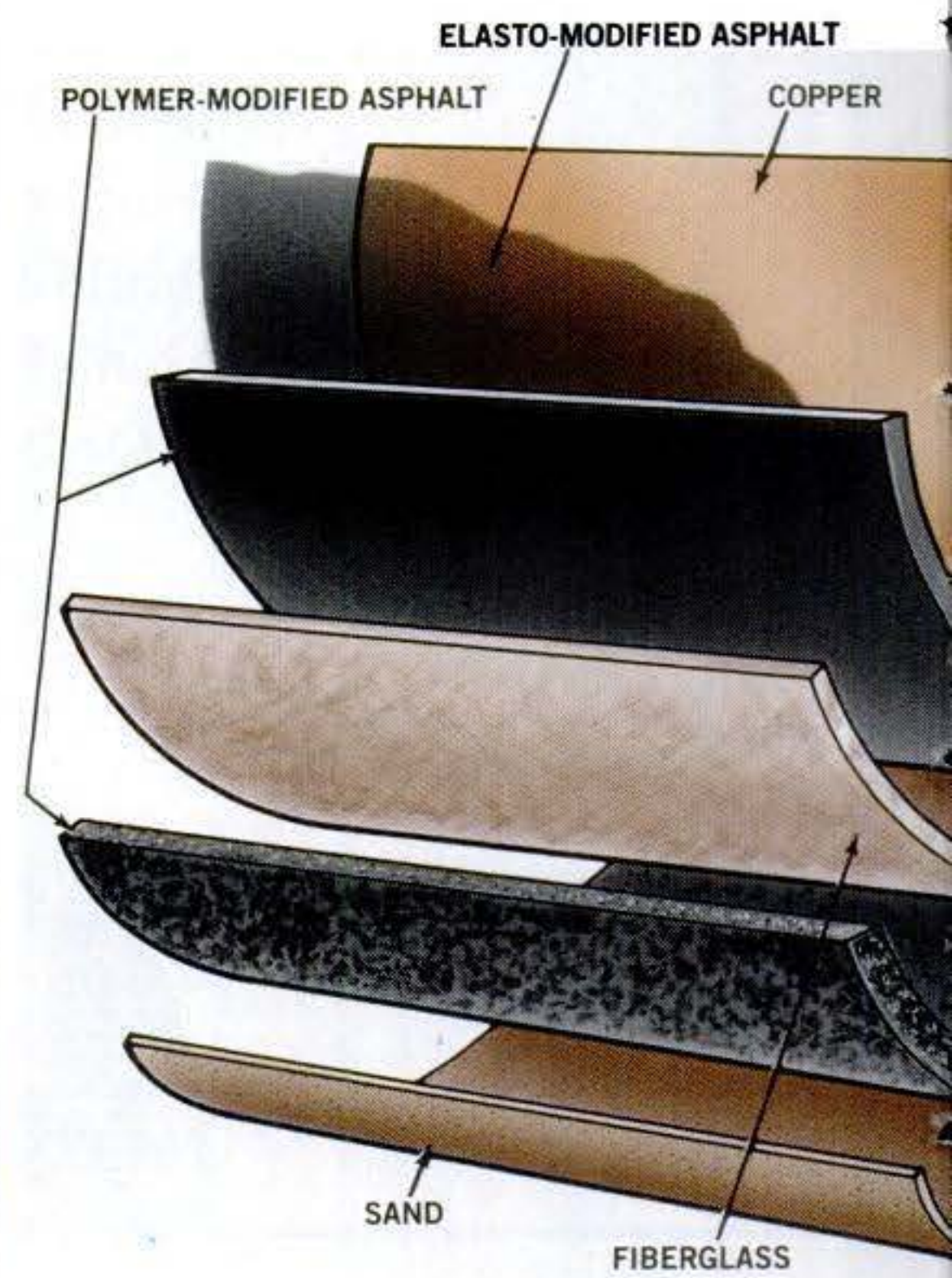
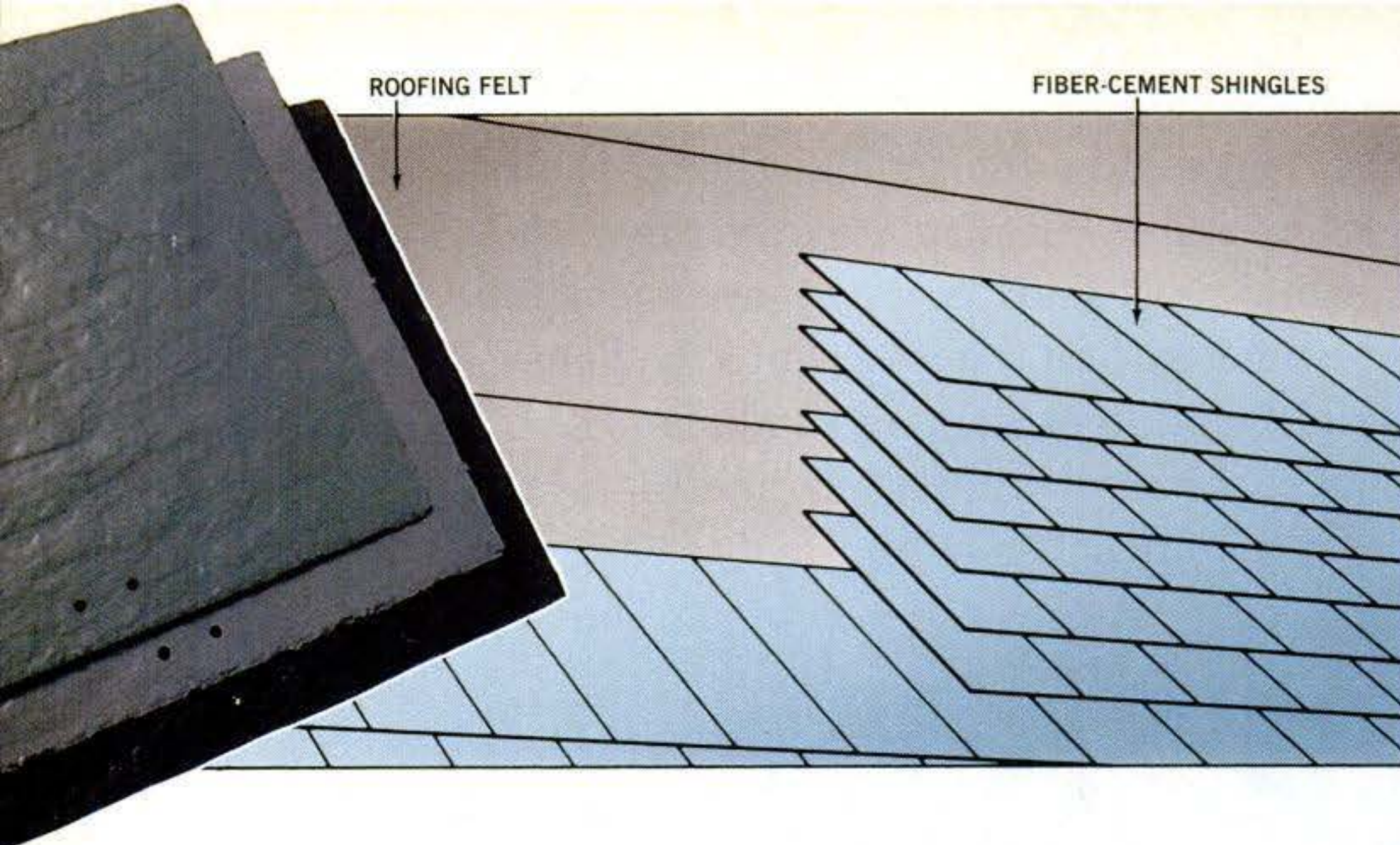
Eternit "slate"—is made of fiber cement. Two other kinds of tile are made of long-lasting lightweight concrete. Finally, one of the best roofing materials, copper, is married with the latest polymer and manufacturing technologies in new copper-asphalt composite shingles.

Fiber cement is a remarkable new substance that has been developed to take the place of asbestos-based materials. (Asbestos, of course, is a carcinogen.) It is made with portland cement, natural or synthetic fibers, silica, and nontoxic additives.

"We use both synthetic and organic fibers like cellulose in our fiber cement," says Bob Nabholz, director of

engineering for Eternit. FibreCem, another manufacturer of fiber-cement "slate," and MaxiTile Inc., maker of fiber-cement Spanish-style tile, use only cellulose. "Fiber cement exhibits properties similar to asbestos products—durability, fire resistance—without the health hazards," Nabholz told me. "The fiber provides strength, and we use amorphous silica for wear resistance. The portland cement holds everything together. Additives include pigments for running color entirely through the material." Fiber cement makes for a premium, long-wearing, fire-resistant roofing material: MaxiTile and FibreCem slate are warranted

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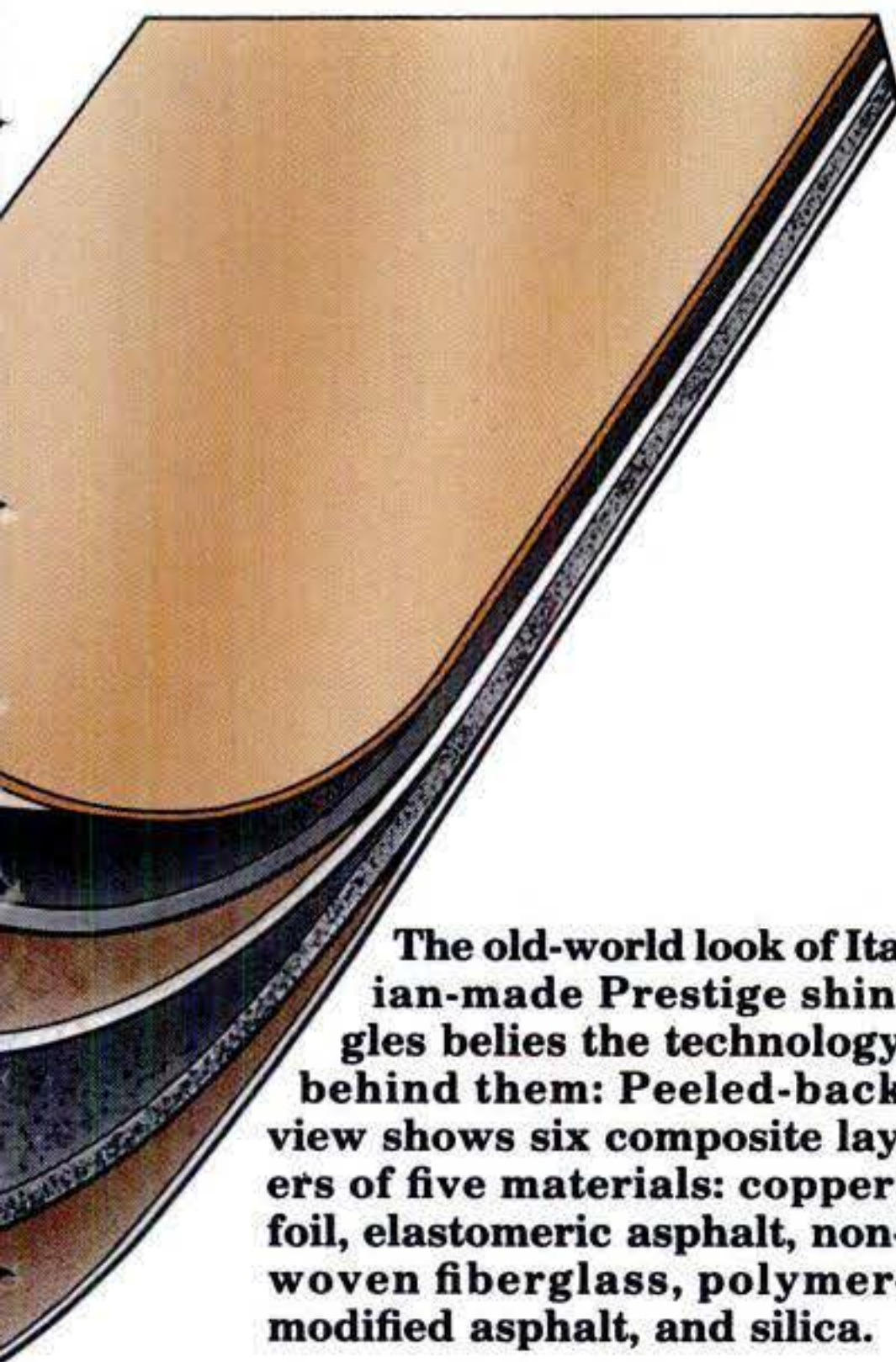
for 50 years; Eternit slate for 30.

All three products are made in Europe, but plans are underway for U.S. plants. "The manufacturing process takes place in four steps," says George Suter, president of FibreCem. "The initial mixture resembles cake batter. That is run through a machine like a paper press. The resulting large sheets are dried in an autoclave like those used in the pulp industry, then the cured sheets are cut to size and packaged."

The advantages of fiber cement over slate and clay are lower weight and cost with similar wear- and fire-resistance characteristics. Its price is approximately half that of natural slate.



Handsome, inexpensive alternatives to natural slate, roofing slates made from cellulose or mineral fiber, cement, and silica look and perform like the real thing. Eternit's black, gray, or green slates (top left) are installed over roofing felt with a four-inch head lap (drawing). Beaver tail shingles from FibreCem (middle) are aptly named and give a roof textural detail. Mediterranean-style MaxiTiles (bottom) come in two-by-three-foot sections for ease of application and an installed weight of only 3.4 pounds per square foot, much lighter than conventional tile.



The old-world look of Italian-made Prestige shingles belies the technology behind them: Peeled-back view shows six composite layers of five materials: copper foil, elastomeric asphalt, non-woven fiberglass, polymer-modified asphalt, and silica.



Mediterranean-look tile takes another new form: Vanguard Roll roofing is made of a special lightweight concrete.

Its concealed double-interlocking weatherproof design requires fewer assembly pieces per square (drawing left) for a 50-year life.

Where MaxiTile uses fiber cement in place of clay in its Mediterranean-style tile, Gory Roof Tile and Monier Roof Tile use what might be considered an unlikely material: concrete. The Gory Vanguard Roll tile has a special double-roll profile and interlocking design that make for a weathertight installation using only nails and no mortar. The new tongue-in-groovelike double-interlocking design results in fewer assembly pieces per square (a roofer's measurement—100 square feet) because it does away with the overlapping in conventional tile.

Monier Styleline tiles have a unique feature: unusually smooth, contoured edges rather than hard, 90-degree edges

found in other tiles. The installed look is more elegant, as it does away with the distinct shadow line between rows of tile. Another unusual feature is Monier's ability to computer-blend up to four colors in any tile.

Even traditional high-end copper roofing is being updated with new technology. The Prestige copper shingle is a laminated composite of copper, asphalt, fiberglass, and sand. "The base carrier is a waterproof membrane of fiberglass impregnated with polymer-modified bitumen, essentially a super-flexible longer-lasting asphalt," says Carmen Simeone, senior vice president of Makielski Reed Corp., the U.S. importer. "A new rolling technology

has enabled the Italian manufacturer, Tegola Canadese, to produce copper sheeting ten times thinner than ever before—eighty microns. This is bonded to the base with a super-adhesive elasto-modified asphalt."

The resulting shingle is applied like conventional asphalt shingles, so installation is much easier than with traditional standing-seam copper roofing. The installed price, at \$3.50 a square foot, is one-third the cost.

ROOFING SOURCES

Eternit, Inc., Village Center Dr., Reading PA 19607; Fibre-Cem Corp., 7 Woodlawn Green, Charlotte NC 28217; Gory Roof Tile, 1100 Park Central Blvd. S., Pompano Beach FL 33064; Makielski Reed Corp., 9015 Woodyard Rd., Clinton MD 20735; MaxiTile, Inc., 15000 Staff Ct., Gardena CA 90247; Monier Roof Tile, Box 5567, Orange CA 92613-5567

EXTERIORS AND OUTSIDE INSULATION

Stucco is a fine traditional building material. But it is labor intensive and slow to apply, usually requiring three coats with a week of curing between each coat. And although stucco is strong, it's rigid, which often leads to hairline cracking from expansion and contraction over time.

Now a number of new, innovative exterior products provide the look of

stucco, but avoid its problems. They include coatings such as Stuc-O-Flex from Perma-Chink Systems, exterior panel-coating systems like United States Gypsum's Durock Exterior Finish and Eternit's Eterspan, and exterior panel systems with insulation such as Senergy's Senerflex, Sto's EIFS, and Ispo Inc.'s R-wall.

Once you've insulated the outside shell of your house, you may want to

insulate below grade, especially in new construction. New insulating systems from The Dow Chemical Co., Gentrex Corp., and Plymouth Foam Products let you insulate—and in one case simultaneously waterproof—your basement or foundation walls from the outside.

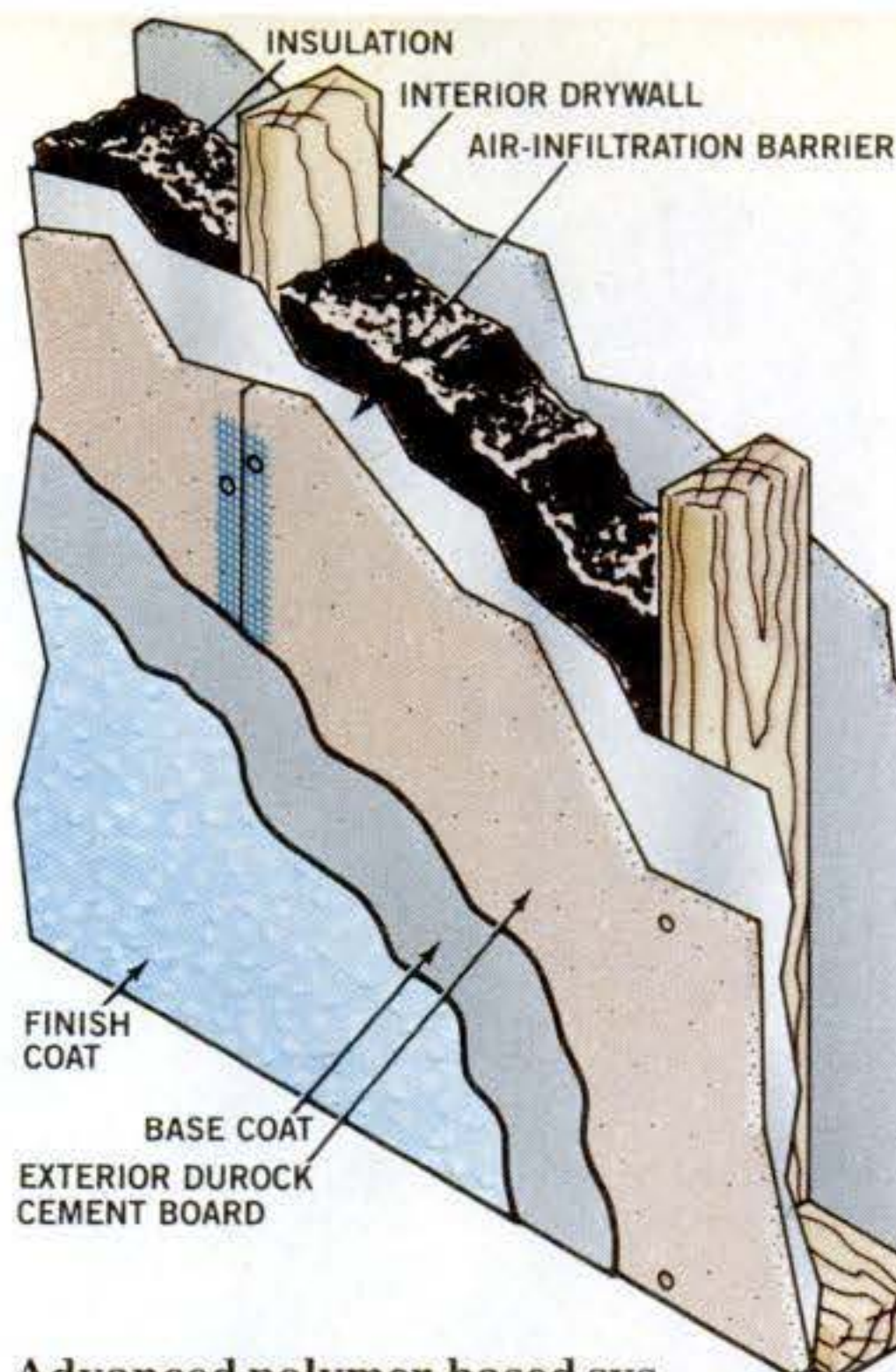
"Flexibility is important in an exterior coating," says Stan Gaylon, man-

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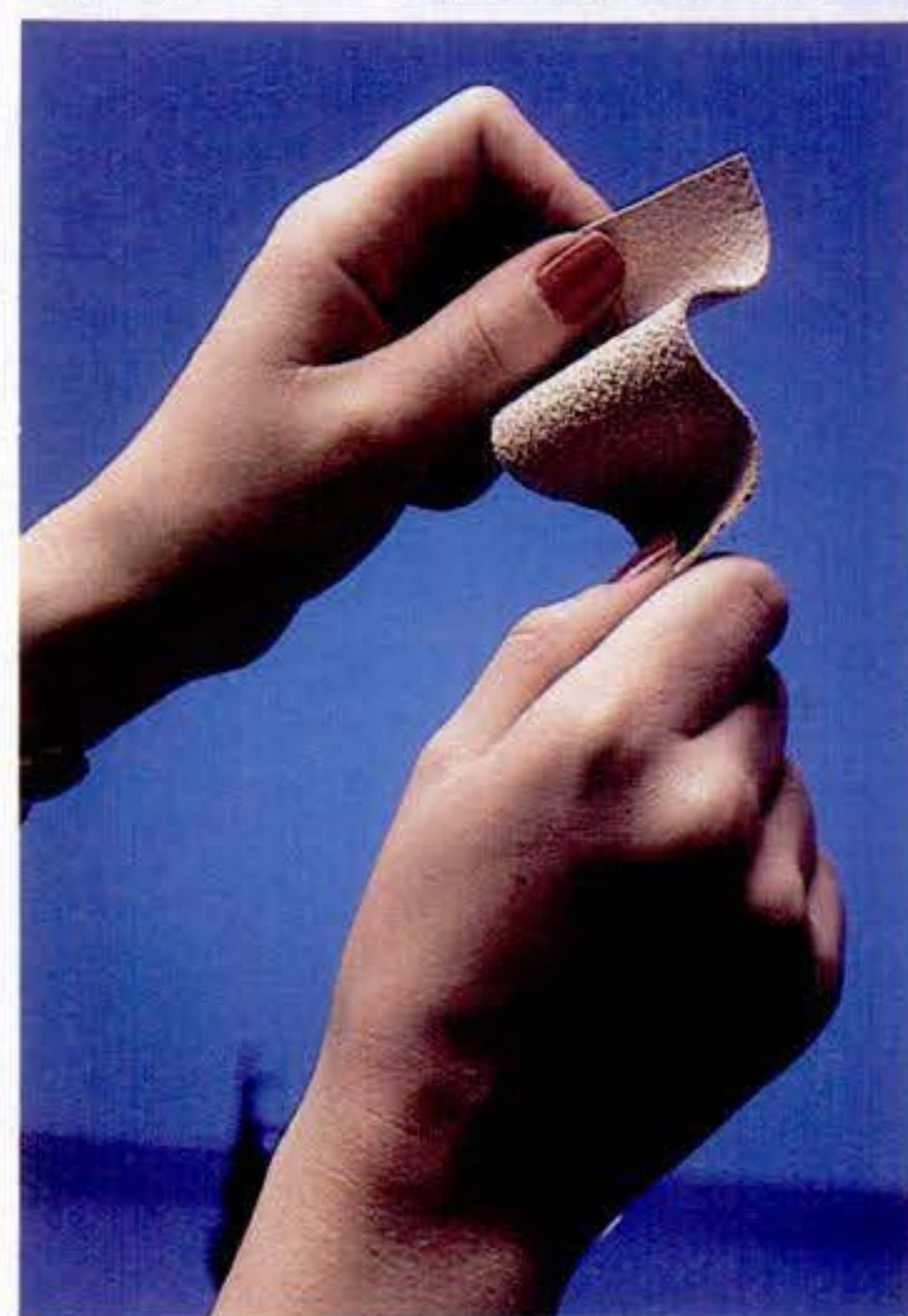
ager of research and development at Perma-Chink Systems, the maker of Stuc-O-Flex, "but our coating has a special property, true elongation. We have taken advantage of the recent exponential growth in polymer technology in our styrenated-acrylic coating: It can stretch 105 percent without breaking to withstand expansion of the substrate and building movement through settling without producing hairline cracks."

According to Gaylon, accelerated weathering tests by an independent laboratory have passed the 10-year mark, a standard in the industry, and Stuc-O-Flex has exhibited minimal fading and no chipping, peeling, or cracking. The coating is usually applied as a three-part system of a base coat, a fiberglass reinforcing mesh, and a troweled or sprayed topcoat. The topcoat may be used alone in a retrofit, however. An entire house—2,000 to 3,000 square feet of outside walls—can be coated in one to two days, says Gaylon.

Another acrylic exterior coating, Durock Exterior Finish from United States Gypsum, uses cement board as a base substrate. The portland-cement-



Advanced polymer-based systems like Durock Exterior Finish (above) and Stuc-O-Flex (right) give stucco a new dimension. Durock siding is a multi-component system consisting of cement-board sheathing, elastomeric base coat, and acrylic polymer exterior finish. Stuc-O-Flex is a latex polymer coating that, sprayed or troweled on, looks like traditional stucco, but is remarkably flexible.



Exterior finishes like those from Sto (left) give a stucco look with the added benefit of insulation. Typically, foam insulation is fastened to a substrate, reinforced with fiberglass mesh, and covered with a moisture-resistant elastomeric coating (see cutaway).



and-mortar-based board is similar to USG's interior tile-backer board. The elastomeric coating is an acrylic polymer emulsion engineered for a strong chemical bond to the base coat and cement-board substrate. An alternative to the Durock cement-mortar board/finish is Eternit's Eterspan, a fiber-cement board made with technology similar to the company's synthetic slate. Any exterior coating may be added to Eterspan.

Exterior insulation and finish systems like Senergy Inc.'s Senerflex, Sto Industries' EIFS, and Ispo Inc.'s R-wall put foam-panel insulation on the outside of the wall, directly onto the sheathing in new construction or

over existing siding in retrofit jobs.

"With insulation on the outside," says Buck Buchanan, vice president-marketing of Sto Corp., "you get effective, continuous protection, eliminating thermal voids, or areas around receptacles and windows where insulation may be lacking or inadequate. The coating provides a tough, impact-resistant face for the foam insulation, which you can also use to create sculptured architectural detailing."

Once the insulation is attached to the building, a reinforcing membrane, usually a woven fiberglass mesh, is applied and embedded in a mortarlike base coat. The respective topcoat is then sprayed or troweled on, for a stuccolike look.

Finally, for complete exterior-insulation protection, there are new systems for foundations and basements. Dow Chemical's Styrofoam Thermadry uses the water resistance inherent in its Styrofoam plastic foam insulation



A new foam panel from Dow insulates basement walls to improve the thermal performance of your house; it also waterproofs below-grade walls. Styrofoam Thermadry panels (above) provide an insulating value of R-4.6 per inch of thickness and are grooved to form channels that carry away water before it can damage your foundation. Tough spun-bonded filtration fabric prevents channel clogging.

to provide a waterproofing-insulating panel. A grid of horizontal and vertical channels on the outside of the panel allows ground water to drain away before it reaches the foundation/basement wall (see drawing); the closed-cell structure of the Styrofoam extruded polystyrene minimizes water absorption by the panel. A nonwoven fiberglass mat is bonded to the panel to filter the water and keep the channels from becoming clogged with sand or aggregate. You bond the tongue-and-grooved panels to waterproof-treated foundation walls with mastic, keeping the channels facing outward. Gravel backfill and drainage tiles or piping at the footing complete the installation. Thermadry panels come in 1.5- or 2.25-inch thick panels for insulating values of R-6.4 or R-10.4, respectively.

The Dow system, for all its waterproofing and insulating capabilities, can't present a finished surface when part or all of a basement/foundation wall is exposed. For that you might use one of two new precoated foam-panel products: Polyskirt, from Plymouth Foam Products, and Gentrex System 150.

Polyskirt, available in either expanded polystyrene foam or Dow Styrofoam extruded polystyrene foam

panels, is covered with a tough polyolefin vinyl facing to protect the otherwise delicate surface of the foam panels. The two-by-four-foot size is entirely protected; the four-by-eight-foot panels have only the top two feet covered. After you attach special channels to the foundation wall, you slip in the insulation panels and attach them to the wall with adhesive or bolts.

Gentrex System 150 panels also have a vinyl facing, but they are intended primarily for new construction. They replace concrete forms for slab-on-grade foundations or for footings. When the concrete is poured, it fills a keyway routed into the rear of the panel, forming a mechanical tie with the panel. System 150 is available with either one- or two-inch Styrofoam panels; it is not available in expanded polystyrene bead board.

EXTERIOR FINISH AND OUTSIDE INSULATION SOURCES

The Dow Chemical Co., 2020 Willard H. Dow Center, Midland MI 48674; E. I. Du Pont de Nemours & Co., Laurel Run Bldg., Box 80705, Wilmington DE 19880-0705; Gentrex Corp., 46400 80th St. W. Lancaster CA 93536; Ispo, Inc., 792 S. Main St., Mansfield MA 02048; Perma-Chink Systems, Inc., 17455 NE 67th Ct., Redmond WA 98052; Plymouth Foam Products, 1800 Sunset Dr., Plymouth WI 53073; Senergy Inc., 1367 Elmwood Ave., Cranston RI 02910; STO Industries, 6175 Riverside Dr. S.W. Atlanta GA 30331; United States Gypsum Co., 101 S. Wacker Dr., Chicago IL 60606-4385

SOFT PAVERS

Your two-year-old trips and falls while running on the patio. No crying? No skinned knees? No blood? Not if your patio is made of Softpave.

This innovative paving material consists of one-inch-thick resilient interlocking tiles made of shredded rubber from recycled tires and dyed attractive shades of red, green, gray, and flecked black. Softpave can be used inside or out, says Carlisle Tire and Rubber Co., for recreational or athletic areas—anywhere you might want a resilient surface.

"We got the idea for using recycled tires for pavers from Europe," Walt Henderson, group product manager for Carlisle, told me. "Germany has been making products from recycled tires for years, and the trend has recently spread to England and France." Another U.S. company, J&J Trading Inc., in Chester, Pa., makes trash-can lids, fence posts, and domestic waste pipes from recycled tires.

"We purchase shredded rubber from

Continued

Softpave tiles—resilient pavers for walkways, exterior and interior sporting areas like tennis courts or weight rooms, or just a soft patio—are made from recycled tires in an interlocking design.



tire recyclers, mix the rubber with adhesive binders and dyes, and pour the mixture into molds," says Henderson. "There it is heated under high pressure, then cured. It took quite a bit of development work to overcome problems like maintaining a homogeneous mix during the entire process. Another difficulty involved developing a forming mold-release process to achieve

the smooth surface we needed under such high temperature and pressure conditions."

The red, green, and gray dyed pavers (recycled rubber is black) are not intended for use in high traffic areas or around pools because the color tends to wear off under constant use and fade in the presence of chlorine. There is no problem using the flecked

tile, however, because most of the material is in its natural black state and should not fade. A new tile, with a thin layer of light-colored virgin rubber laminated to the surface, is on the horizon for use on pool decks and other demanding applications where you might not want dark-colored tiles. Carlisle Tire and Rubber Co., Box 99, Carlisle, Pa. 17013.

INNOVATIVE LUMBER

Two new building products, one made from natural materials and the other synthetic, make the job of trimming and framing houses easier.

Weyerhaeuser's new Clear-Type Exterior (CTX) Trim is an engineered wood product, basically a medium-density fiberboard, but with a big difference. Manufactured in a new plant in Broken Bow, Okla., CTX is produced in a new steam-injection technology press, the only one like it in the United States, according to the company. Says Weyerhaeuser's marketing manager Jerry LeClaire: "We mix wood fibers, refined from southern pine chips and

planer shavings, with phenolic resin and emulsified wax to form a fluffy mat. The mat is placed in the press to undergo a computer-controlled pressing cycle. During the pressing cycle, live steam under a pressure and vacuum sequence is injected into the fiber mat to raise the interior temperature of the mat quickly and uniformly. This process reduces the resin curing time sixfold and results in a uniformly dense board."

After the CTX mat is cured, it is cut into boards of various lengths and widths. The boards are then primed for painting, and this involves another new-technology development. CTX



The S-curve at far left demonstrates the physical and design flexibility of Billee-Bord plastic framing lumber. The board is oversized by a half-inch (the thickness of a sheet of drywall) and has a ridge on its end that acts as a corner bead when drywall is nailed to the studs and finished. For round-top windows (top of next page), the "lumber" is simply bent into place and braced. Drywall is not required on the inside of the arch.

boards are primed in a special painting process that coats all six sides of individual pieces simultaneously. The coating is complete, and it provides a sound, trouble-free base for exterior paints, says LeClaire.

Weyerhaeuser claims its trim eliminates warping and cupping problems and is resistant to water, decay, mildew, checking, splitting, and twisting. And unlike other, conventional hardboard, CTX trim does not have a difficult-to-work-with extra-hard surface and softer interior. Because of the unique curing process, says LeClaire, CTX resembles more-conventional lumber with its uniform density: Starting and setting nails is easier.

CTX trim is nonstructural; that is, it is intended as decorative lumber only, LeClaire told me. It can be cut and nailed with ordinary woodworking tools. The trim material is made in nominal 1-, 5/4-, 3/4- and 2-inch thicknesses; nominal widths of 4, 6, 8, 10, and 12 inches; and actual 8-, 16-, 18-, and 20-foot lengths. Weyerhaeuser, Box 467067, Atlanta, Ga. 30346.

A remarkable new framing material,



Imaginative Materials Group's new plastic Billee-Bord, allows you to frame out round-top windows or curved walls by simply bending the board to shape—down to a two-foot radius.

"Once the lumber is nailed to the supporting structure, it remains in place," says Millard Thacker, president of IMG. "It is flexible enough so that it won't try to return to its original shape and create stress in the framing. And it can be cut, nailed, painted, and screwed with conventional woodwork-

ing equipment."

Billee-Bord is made of pliable polyurethane, and it comes in slightly oversize lumber sizes—1½ by 4 and 1½ by 6 inches, and in 8- and 10-foot lengths. The board is slightly oversize because of an interesting feature: A ridge that runs along its edge acts as a corner bead for finishing drywall. Installed to form a round-top archway for instance, you butt the drywall up to the Billee-Bord (it is ½ inch oversize to take the thickness of the drywall) so that the surfaces of the drywall and the board are flush. You just tape the joint, with the raised ridge acting as the spackle bead. There's

no need for fitting and finishing drywall inside the arch.

Billee-Bord is not intended as a stud in conventional framing, but serves as a base and sill in a curved wall (see photo) or as the frame for a rounded opening. When using Billee-Bord you should finish walls on the beaded side with ½-inch drywall only. Any other thickness will defeat the purpose of the easy-finishing design. Imaginative Materials Group, 1580 Industrial Ave., Norco, Calif. 91760.

QUIET WOOD FLOOR

Wood floors are more popular than ever. But on upper-story floors they can be noisy for those below, transmitting all the taps, clicks, and bumps—noise from toys, walking, moving furniture—that are part of everyday living. Can you have the beauty of bare wood and the quiet too?

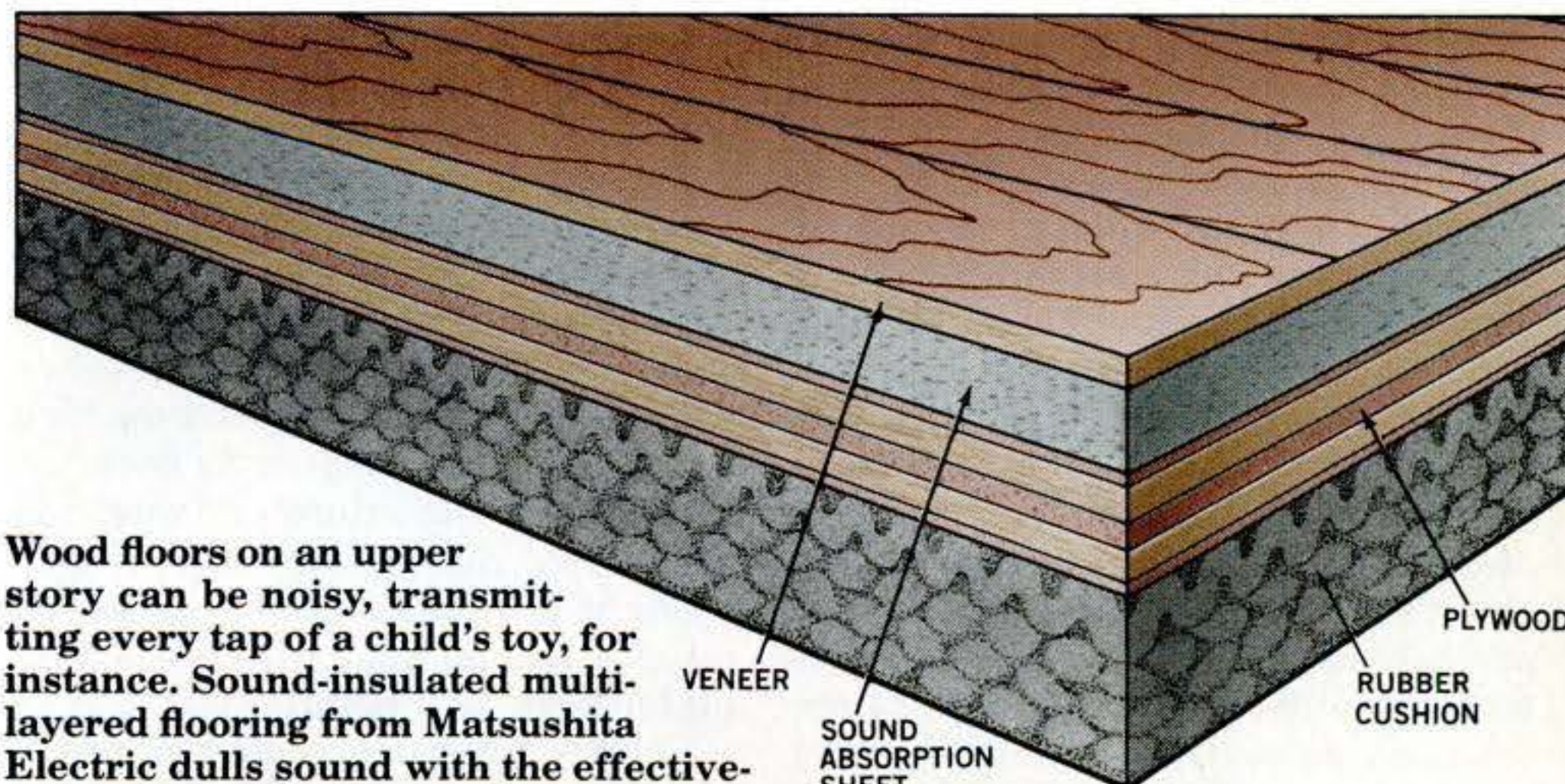
Japan's Matsushita Electric Works may have come up with a solution in its fascinating Sound Insulation Flooring (see drawing). The heart of the multilayered wood flooring system is a so-called Sound Absorption Sheet. Located beneath the surface wood veneer, the sheet is a dense mat composed of minute solid polymer particles in a resin base. Matsushita claims that not only do the polymer particles absorb sound, but friction between the particles and the special resin base also helps in sound attenuation.

Furthermore, the flooring system uses a rubber cushion similar to carpet cushioning that is separated from the

Sound Absorption Sheet by a layer of plywood. Matsushita says the isolation produced by the foam cushion, along with the sound attenuation of the polymer-resin sheet, effectively stops vibration from being transmitted through the one-inch-thick flooring.

The Sound Insulation Flooring is

suited to application over an upper-story concrete slab. Sound is readily transmitted through solid concrete, and the isolation the flooring provides reduces overhead noises, says the company. Matsushita Electric Works Ltd., 401 River Oaks Parkway, San Jose, Calif. 95134. **PS**



Wood floors on an upper story can be noisy, transmitting every tap of a child's toy, for instance. Sound-insulated multilayered flooring from Matsushita Electric dulls sound with the effectiveness of carpeting, says the company, but has the look of a wood floor.

A brief history of *A Brief History*

In which a famed theoretical physicist reveals why he plumbed the nature of the universe and the mind of God in his best seller *A Brief History of Time*.

By STEPHEN W. HAWKING

Generally acknowledged by his peers to be one of the most brilliant theoretical physicists since Albert Einstein, Stephen W. Hawking is Lucasian Professor of Mathematics at Cambridge University, not incidentally the same chair occupied by his illustrious predecessor, Isaac Newton. Hawking has spent most of his career pondering such imponderables as the nature of time and the origins of the universe. His most notable achievement to date has been to elucidate the nature of black holes (whose existence remains to be proven).

*This year Hawking was one of the five recipients of the \$25,000 Britannica awards. He was cited for using his brilliant scientific mind to be a "superb communicator to lay readers of extremely difficult physical concepts," as demonstrated most recently in *A Brief History of Time: From the Big Bang to Black Hole*.*

Hawking's memoir about the origins of the book, printed here, was written in 1988.—Arthur Fisher

I am still rather taken aback by the reception given to my book, *A Brief History of Time*. It has been on *The New York Times* best-seller list for 31 weeks [as of the April 23, 1989, edition of *The New York Times*, Hawking's book has been on the best-seller list for 53 weeks] and on *The Sunday Times* [of London] list for 26 weeks. (It was published later in Britain than in the United States.) And it is being translated into 20 languages (21 if you count American as different from English). This was much more than I expected when I first had the idea in 1982 of writing a popular book about the universe. The intention was partly to earn money to pay my daughter's school fees. (In fact, by the time the book actually appeared, she was in her last year of school.) But the main reason was that I wanted to explain

how far I felt we had come in our understanding of the universe. How we might be near finding a complete theory that would describe the universe and everything in it.

If I were going to spend the time and effort to write a book, I wanted it to get to as many people as possible. My previous technical books had been published by Cambridge University Press. That publisher had done a good job, but I didn't feel that it would really be geared to the sort of mass market that I wanted to reach. I therefore contacted a literary agent, Al Zuckerman, who had been introduced to me as the brother-in-law of a colleague. I gave him a draft of the first chapter and explained that I wanted it to be the sort of book that would sell on airport book stalls. He told me there was no chance of that: It might sell well to academics and students, but a book like that couldn't break into Jeffrey Archer territory.

I gave Zuckerman a first draft of the book in 1984. He sent it to several publishers and recommended that I accept an offer from Norton, a fairly up-market American book firm. But I decided instead to take an offer from Bantam, a publisher more oriented toward the popular market. In fact, I believe my book was the first science book that Bantam had accepted. That it did so was probably because of the interest taken by one of its editors, Peter Guzzardi. He took his job very seriously and made me rewrite the book to make it understandable to non-scientists like himself. Each time I sent him a rewritten chapter, he sent back a long list of objections and questions he wanted me to clarify. At times I thought the process would never terminate. But he was right: It is a much better book as a result.

Shortly after I accepted Bantam's offer I got pneumonia. I had to have a tracheotomy operation that removed

my voice. For a time I could communicate only by raising my eyebrows when someone pointed to letters on a card. It seemed quite impossible to finish the book. But a software expert in California named Walt Wolosz heard of my plight. He sent me a computer program that allowed me to write and speak by pressing a switch as the computer scanned lists of words on the screen. It was a bit slow, but then I think slowly, so it suited me quite well. With it I almost completely rewrote my first draft in response to Guzzardi's urgings. I was helped in this revision by one of my students, Brian Whitt.

I had been very impressed by [Jacob] Bronowski's television series, "The Ascent of Man" (such a sexist title would not be allowed today). It gave a feeling for the achievement of the human race in developing from primitive savages only 15,000 years ago to our present state. I wanted to convey a similar feeling for our progress toward a complete understanding of the laws that govern the universe. I was sure that nearly everyone was interested in how the universe operates, but most people cannot follow mathematical equations. I don't care much for equations myself. This is partly because it is difficult for me to write them down, but mainly because I don't have an intuitive feeling for equations. Instead, I think in pictorial terms. My aim was to describe these mental images in words with the help of familiar analogies and a few diagrams. In this way, I hoped that most people would be able to share in the excitement and feeling of achievement in the remarkable progress that has been made in physics in the last 25 years.

Even if one avoids mathematics, some of the ideas are unfamiliar and difficult to explain. This posed a problem: Should I try to explain them and risk people being confused, or should I

Continued



MIKE YAMASHITA, WOODFIN CAMP & ASSOCIATES

Stephen Hawking musing (above) and en famille. Funding daughter Lucy's education provided the stimulus for *A Brief History*.



HOMER SYKES, WOODFIN CAMP & ASSOCIATES

gloss over the difficulties? Some unfamiliar concepts, such as the fact that observers moving at different velocities measure different time intervals between the same pair of events, were not essential to the picture I wanted to draw. Therefore I felt I could just mention them, but not go into them in depth. But some difficult ideas were basic to what I wanted to get across.

There were two such concepts in particular that I felt I had to include. One was the so-called "Sum Over Histories." This is the idea that there is not just a single history for the universe, and all those histories are equally real (whatever that may mean). The other idea, which is necessary to make mathematical sense of the Sum Over Histories, is "imaginary time." With hindsight, I now feel that I should have put more effort into explaining these two very difficult concepts, particularly imaginary time, which seems to be the thing in the book with which people have the most trouble. However, it is not really necessary to understand exactly what imaginary time is, just that it is different from what we call "real" time.

After he had finished demanding changes in the manuscript, but before the book was actually published, Peter Guzzardi left Bantam for another publishing house. The people who took over responsibility for my book from him obviously got cold feet about it, for they ordered only a fairly small first printing, which would have covered only a small part of the advance Guzzardi had paid me. However, the changeover at Bantam led to such confusion that the first printing contained a large number of errors, like photographs and diagrams being in the wrong places or wrongly labeled. They therefore had to recall it before it got to the shops and do another printing. By then, *Time* magazine had published a profile of me. This encouraged Bantam to make the print order rather large. Even so, the editors were taken by surprise by the demand. The book is in its 17th printing in America and its 10th in Britain.

Why did so many people buy it? It is difficult for me to be sure that I'm objective, so I thought I would go by what other people said. I found most of the reviews, although favorable, rather unilluminating. They tended to follow the formula: Stephen Hawking has Lou Gehrig's disease (in American reviews), or Motor Neuron disease (in British reviews). He is confined to a wheelchair, cannot speak, and can only move "x" number of fingers (where "x" seems to vary from one to three, according to which inaccurate article the reviewer read about me). Yet he has written this book about the biggest question of all:

Where did we come from, and where are we going to? The answer that Hawking proposes is that the universe is neither created nor destroyed: It just is. In order to formulate this idea, Hawking introduces the concept of imaginary time, which I (the reviewer) find a little hard to follow. Still, if Hawking is right and we do find a complete unified theory, we shall really know the mind of God. (In the proof stage I nearly cut the last sentence in the book, which was that we would know the mind of God. Had I done so, the sales might have been halved.)

Rather more perceptive (I felt) was an article in *The Independent* [a London newspaper] that said that even a serious scientific book, like *A Brief History of Time*, could become a cult book. My wife was horrified, but I was rather flattered to have my book compared to *Zen and the Art of Motorcycle Maintenance*. I hope, like *Zen*, that it gives people the feeling that they need not be cut off from the great intellectual and philosophical questions.

Undoubtedly, the human-interest story of how I have managed to be a

theoretical physicist despite my disability has helped. But those who bought the book from the human-interest angle may have been disappointed because it contains only a couple of references to my condition: The book was intended as a history of the universe, not of me. This has not prevented accusations that Bantam shamefully exploited my illness and that I cooperated with this by allowing my picture to appear on the cover. In fact, under my contract I had no control over the cover. I did, however, manage to persuade Bantam to use a better photograph on the British edition than the miserable and out-of-date photo used on the American edition. Bantam will not change the American cover, however, because it says that the American public now identifies that with the book.

It has also been suggested that people buy the book because they have read reviews of it or because it is on the best-seller list. But they don't read it: They just have it in the bookcase or on the coffee table, thereby getting the credit for having it without taking the effort of having to understand it. I am sure this happens, but I don't know that it is any more so than for most other serious books, including the Bible and Shakespeare. On the other hand, I know that some people at least must have read it because each day I get a pile of letters about my book, many asking questions or making detailed comments that indicate that they have read the book, even if they don't understand all of it. I also get stopped by strangers in the street who tell me how much they enjoyed it. Of course, I am more easily identified and more distinctive, if not distinguished, than most authors. But the frequency with which I receive such public congratulations (to the great embarrassment of my nine-year-old son) seems to indicate that at least a proportion of those who buy the book actually do read it.

People now ask me what I am going to do next. I feel I can hardly write a sequel to *A Brief History of Time*. What would I call it? *A Longer History of Time*? *Beyond the End of Time*? *Son of Time*? My agent suggested that I allow a film to be made about my life. But neither I nor my family would have any self-respect left if we let ourselves be portrayed by actors. The same would be true to a lesser extent if I allowed and helped someone to write my life story. Of course, I cannot stop someone from writing about my life independently, as long as it is not libelous, but I try to put people off by saying I'm considering writing my autobiography. Maybe I will, but I'm in no hurry. I have a lot of science that I want to do first.

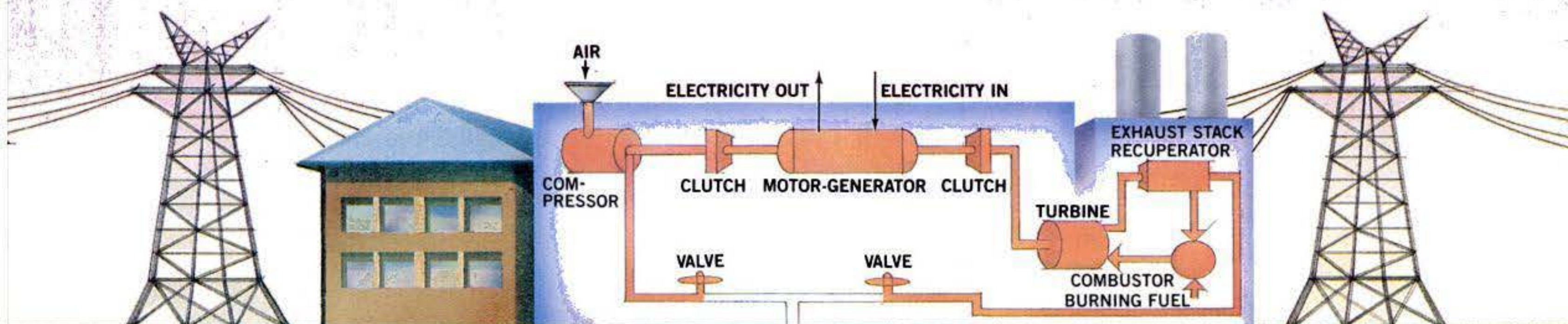
PS

**"I
was rather
flattered to
have my book
compared to
*Zen and the
Art of
Motorcycle
Maintenance*"**

Compressed-air power

Compressed-air energy-storage systems stockpile low-cost power for use during peak-demand periods. Surplus off-peak electricity drives compressors that fill subterranean reservoirs with air. The air is released later to spin turbine-generators.

By STEVEN ASHLEY



When it's summer in southern Alabama, officials at the Alabama Electric Cooperative have a hot time trying to keep consumer electric bills from skyrocketing along with the heat.

The rural utility's big coal-fired power plants usually can satisfy most of its customers' "baseload" electric needs. But when demand doubles as thousands of air conditioners switch on, there's a dilemma: Where can AEC get low-cost energy to meet this transient peak in power demand? Big plants are unsuited to the task. They take a long time to fire up and to shut down. In addition, large plants are economical only when they run around the clock at optimum speed. So AEC must fill the supply gap with medium-priced power from its combustion turbine-generator and with high-priced power from other utilities. Both options mean higher consumer bills.

"Our charter is to find low-cost power for our customers," says Ray Clausen, vice president, corporate planning. "The most attractive peaking-power option is a new technology called compressed-air energy storage [CAES]."

"We're building the world's second commercial CAES plant near McIntosh, Alabama," Clausen says. The cooperative believes it will supply inexpensive power so AEC can handle swings in demand cost-effectively. It will also act as a load-leveling buffer for AEC's baseload plants.

"CAES plants work by using the less-expensive electricity generated by large plants during off-peak hours to compress air into underground caverns or reservoirs," ex-

plains Robert B. Schainker, manager of the energy-storage program at the Electric Power Research Institute (EPRI) in Palo Alto, Calif. EPRI is providing about \$8 million of the \$65 million AEC is spending to build the 110-megawatt plant. During periods of higher energy demand, the air will be released, heated, and then expanded to spin a turbine-generator efficiently (see diagram). By storing low-cost off-peak electricity until it's needed, fuel consumption and the resulting pollution are cut by a third, he says.

The Alabama utility is now pumping water into subterranean salt formations and removing brine to solution-mine a storage cavern, notes John B. Howard, AEC's vice president of power production. When complete, the reservoir will be about 200 feet in diameter and 600 feet deep. This 19-million-square-foot volume will hold air sufficient to drive the plant's turbo-machinery for 26 hours at a time.

Based on a Swedish patent, the world's first commercial CAES plant is a 290-megawatt unit that has operated in Huntorf, West Germany, since 1978, EPRI's Schainker reports. Because reservoirs for compressed air can be built in many formations—salt domes, rock caverns, or aquifer reservoirs—CAES plants can be sited in about three-quarters of the United States, he adds.

If AEC is successful, Schainker predicts that other U.S. utilities will find it easier to try CAES. "The U.S. is behind in energy-storage technology," he says. CAES could be a key to increasing our storage capability, he continues: "Our studies show that CAES could supply about half our country's energy-storage capacity by the year 2020." **PE**

DRAWING BY JANA BRENNING

A CAES plant stores off-peak energy as air compressed into an underground reservoir. A double-duty motor-generator and clutches permit separate compression and generation cycles. At night, low-cost electricity powers the motor-generator, which drives

STORAGE RESERVOIR

the compressor to pump air into storage. In the afternoon, the motor-generator is engaged to the turbine and disengaged from the compressor. The trapped air is released, heated, and expanded through the turbine to produce electricity.

PRESSURIZED AIR

SALT DOME

When a Florida couple decided to build a climate-sensitive house, they and their architect combined today's technology with 19th-century architecture. Making the most of natural ventilation, they're saving their air conditioning—and energy dollars—for emergencies.

COOL HOUSE FOR A HOT CLIMATE



By DAWN STOVER

Mark Zegel grew up in a typical Florida house: concrete block walls on a concrete slab. The tile roof's overhang was small, and the sun beat down on the exterior walls. "I remember, at midnight the walls would still be radiating heat," says Zegel.

Until October 1987 Mark and his wife, Jennifer, lived in a similar house. "It was a stucco-finished concrete-block house with an asphalt shingle roof," he says, "crummy, cheap little windows, and very little insulation." A house like that can be comfortable—all it takes is a big air conditioner and a willingness to use it.

The Zegels had other ideas, however. While vacationing in the Bahamas and Key West they noticed a style of house obviously designed for passive cooling. And they spotted other examples of it while visiting rural areas of their home state. "We like to take the back ways," Mark explains.

Inspired, they decided to build their own "Florida-indigenous-style" house, as Mike Houston, the architect they hired, calls the design. The Zegels

chose many of the vernacular architectural elements they'd seen during their travels: a metal roof, wide porches, an elevated floor, and a cupola. They combined these elements gleaned from the past with modern materials—creating a house that responds quickly to the daily changes in Florida's hot, humid climate.

"The design is simple," says Mark. "Hot air rises." So every room in the house is connected to the central cupola (see drawings). Its windows let in light and let out hot air. Opening the windows on the leeward side of the house takes advantage of the negative air-pressure zone and helps to keep air flowing up through the house, says Houston, an expert on energy-efficient building design who has worked for the Florida Solar Energy Center.

The house is raised about two feet off the ground, so air circulates under the floor. But while Floridians of 100 years ago simply had to swelter when passive cooling wasn't enough, the Zegels have an air conditioner. They stashed it *under* the house, where it's always shady.

The elevated house is exposed to breezes that would otherwise be blocked by palmettos, bushes that are common on Merritt Island, where the

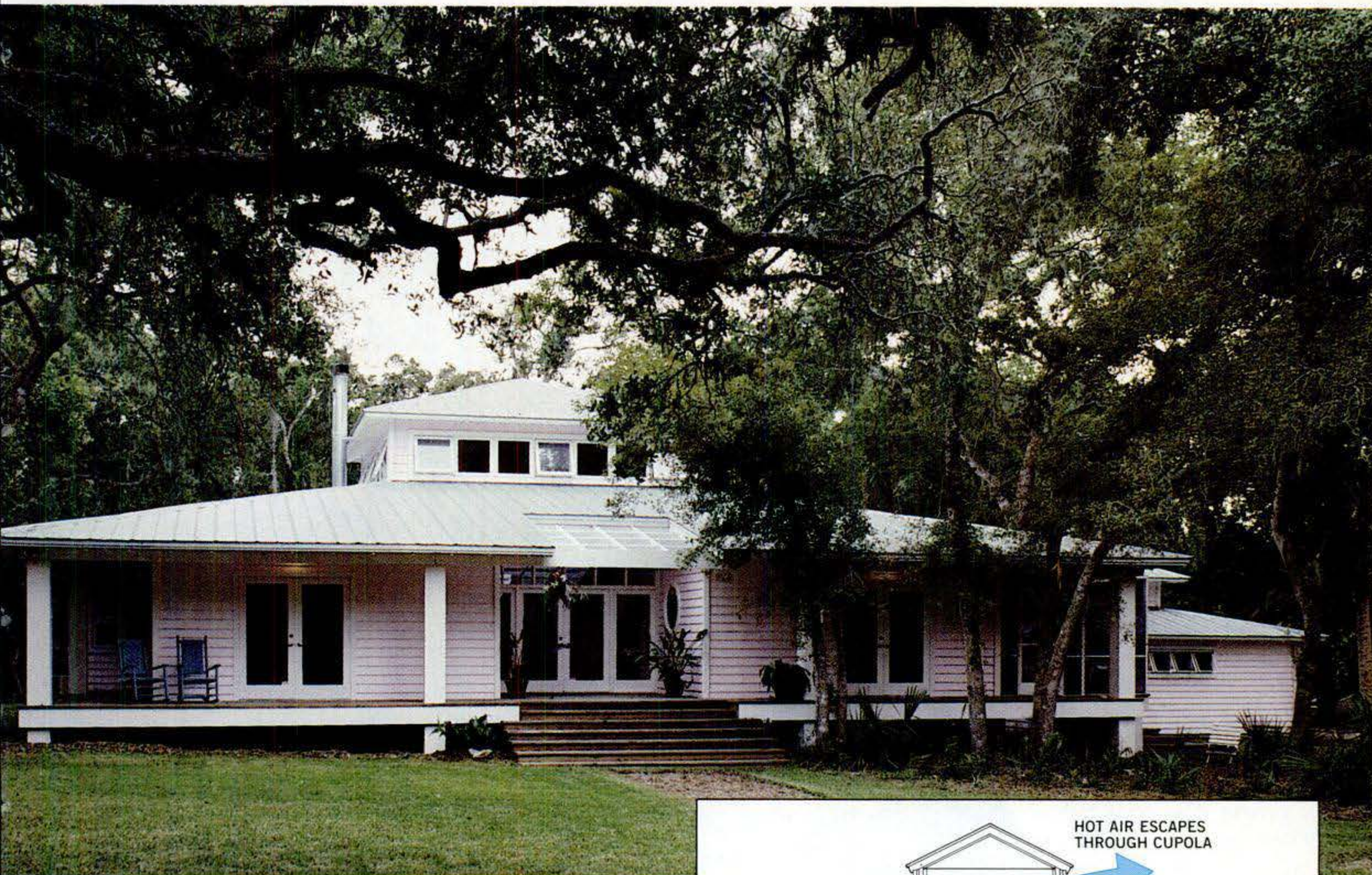
Zegels live. An hour's drive east of Orlando, the island is also home to the Kennedy Space Center.

The house is partially shaded by trees that help cool the surrounding air. "We have live oaks, water oaks, hickories, cedars, and sabal palms—that's the state tree," says Jennifer. She and her husband cleared as few trees as possible; one tree is still growing up through their porch.

The hip roof is made of galvanized steel. "Many old-timers had tin roofs on their houses," says Jennifer. The shiny metal reflects direct sunlight during the day. At night the metal cools quickly.

When it rains, or a hickory nut drops, the metal roof is a bit noisy. But eight inches of insulation help to muffle sounds and reduce heat transmission more effectively than the crumpled newspapers and tin foil used in early Florida houses.

The Zegels wanted to have lots of views to the outside to make the house seem larger. "It's like living in an aquarium," says Mark. Jennifer, an interior designer, wanted to be able to see *through* the house. "We wanted a house that was in tune with nature," she explains. "And that says natural materials. We have a pretty neutral interior, so there's a smooth transi-



PHOTOS BY JOHN B. CARNETT

tion from the outside to the inside."

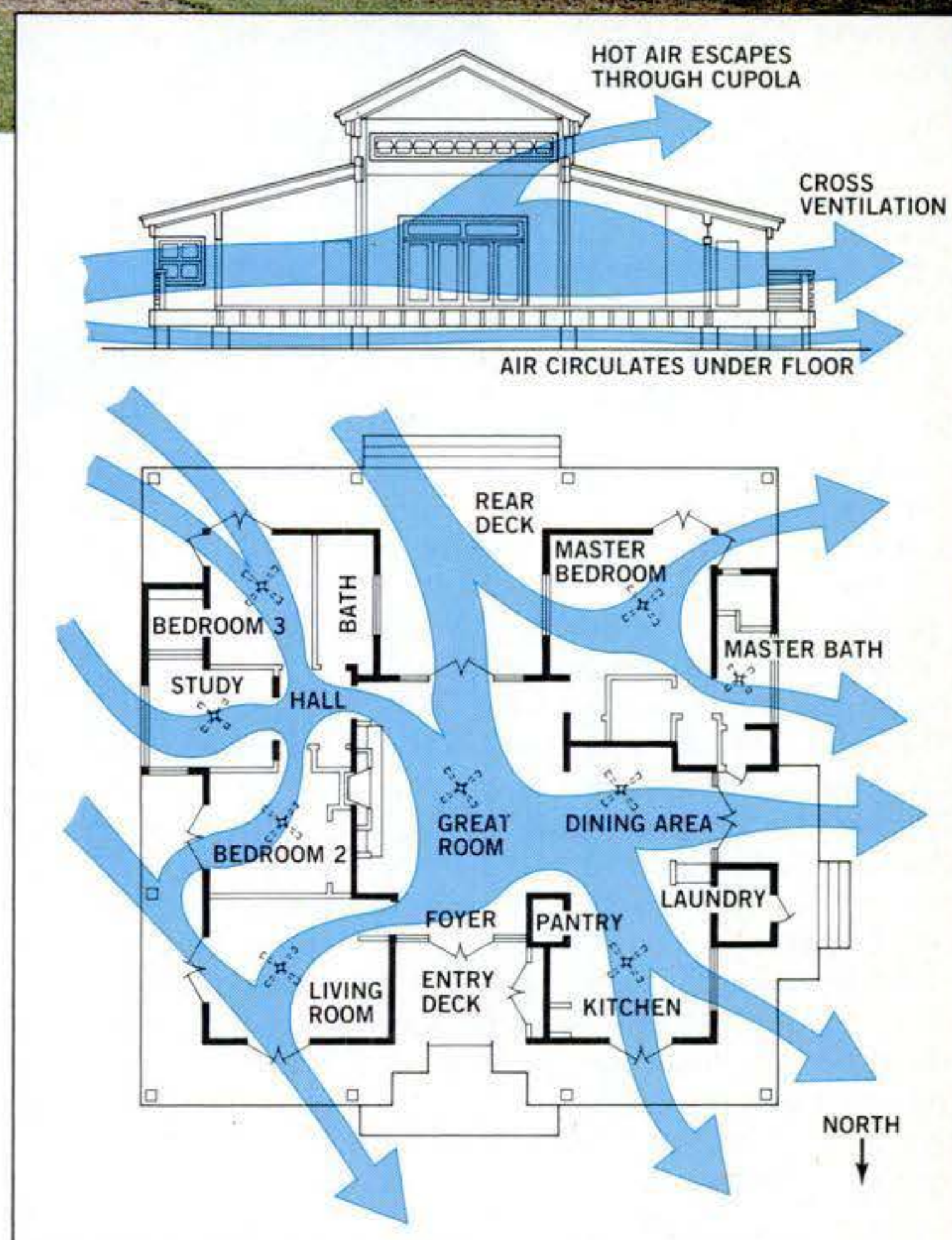
The fireplace is made of keystone, a coral-and-limestone rock native to Florida. The Zegels chose oak floors and ceramic tiles instead of carpets, which soak up moisture in the humid climate. "It gets *sticky* hot in Florida," says Jennifer.

When it becomes unbearable, the Zegels run their dual-zone air conditioning. Even so, Mark says, "our electric bill hasn't topped one hundred dollars." The house, which cost about \$65 a square foot and took five months to construct, has roughly 2,450 square feet of indoor living space, in addition to approximately 1,500 square feet of covered porches. Recalling the 1,800-square-foot tract house he moved out of, Mark says, "We're living in a house that's more comfortable and more spacious, and paying the same price in utilities."

One-story concrete stucco houses aren't going to disappear overnight. To Florida newcomers, they're reassuringly familiar-looking and affordable. "A home similar to what Mark and Jennifer built is not a home for everyone," warns Houston. "It's for people who are concerned about the environment, who want to do their part to save energy, and who are willing to accept a little discomfort." ■

Nature is the focus of the Zegel house, so the interior design is clean and simple (above left). A wide veranda, which surrounds most of the house (above), provides outdoor living space and shade for the full-length windows and double doors. Trees, saved from the chain saw, provide both shade and evaporative cooling. Exploiting summer breezes, which generally come from the south-east, required careful siting of the house. Air flows under the floor, across living areas, and up into a cupola with operable clerestory windows (top drawing). As the air heats, it goes up—and out. The great room (bottom drawing), with a 26-foot ceiling, keeps the warm-

est air away from inhabitants. Awning-style windows provide maximum ventilation area and can remain open in the rain. Ceiling fans disperse the fresh air. The kitchen is situated in the down-wind corner of the house, where its heat can do the least damage.



DRAWING BY MARIO FERRO

Hello, you've reached

I hadn't spoken to my friend Peter, a Manhattan attorney, in months. When I finally called his home, I discovered that something had changed.

"Hi, this is Peter, and I'm not in right now. Here comes the beep. You know what to do."

A few years ago, Peter's answering machine played a tune called "Don't Hang Up," followed by explicit instructions for leaving a message. Today, that isn't necessary. Peter's friends and family *know what to do*.

Abbreviated messages are proof of how commonplace answering machines have become since their migration from the office to the home. Manufacturers expect to sell more than eight million answering machines this year. More than a fifth of all American households already have a telephone answering machine, and people who own the devices use them more frequently than any other electronic product, says the Electronic Industries Association. The machines not only take messages for owners who are away, but also screen out unwanted calls while the owners are at home.

The same people who once complained about having to talk to a machine are now irritated when they phone someone who *doesn't* have one. And callers who stammered after the beep now deliver glib monologues. In big cities, busy professionals have a new way of planning rendezvous: "Have your machine call my machine." When the parties finally connect, they typically apologize for "playing phone tag."

Messages are also becoming more businesslike. Gone are the days when co-workers circulated the phone numbers of answering-machine owners with hilarious greetings. You no longer have to be entertaining to persuade callers to leave messages.

But it's not just messages that are changing. The machines themselves are evolving, with new features appearing every few months. The most significant change is a move toward digital technology. A number of companies—including AT&T, Code-A-Phone, Conair, Panasonic, PhoneMate, Record-A-Call, Sony, and Toshiba—are already selling machines that use random-access-memory chips to store out-

going messages. And at least one company, Code-A-Phone, makes a completely digital answering machine that uses chips for both outgoing and incoming recordings.

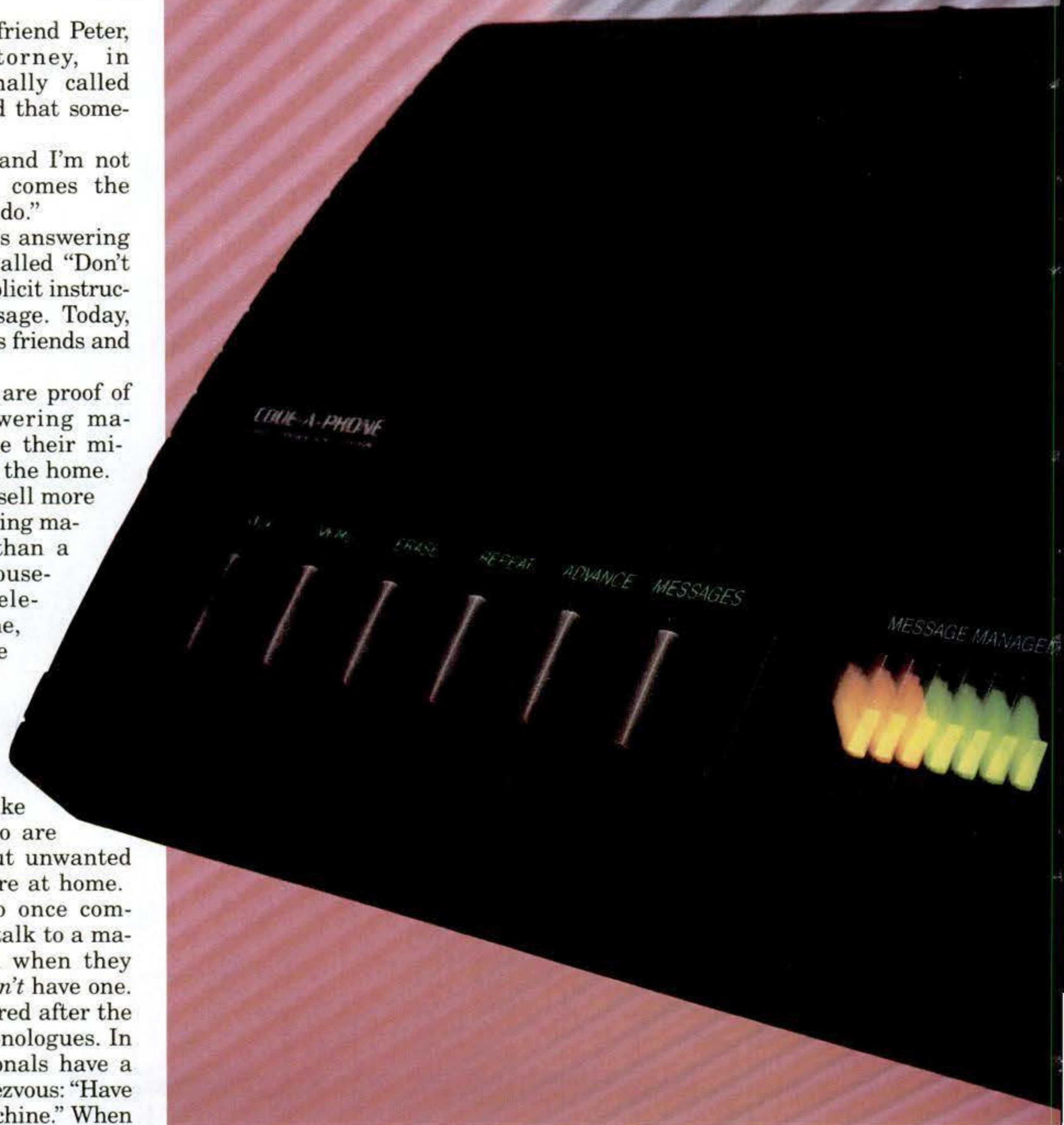
Digital technology is experiencing a few growing pains right now, but it offers many advantages over tape-based systems. Even the companies that aren't currently touting digital machines say that chips are on the way. "Ultimately, all answering machines will be digital," predicts Jim Ristow, vice president for sales and marketing at Record-A-Call.

What can digital do? "The key issue is reliability," says Linda Lybeck, marketing director at Code-A-Phone. "It's like a compact-disc player relative to

a record player. The audio quality will never deteriorate." There's no tape to wear out and no moving parts to maintain.

No tape also means no rewinding, so digital machines are quicker. Again, they're like CD players. "They give you instant access to anything," Lybeck says. And the incoming messages are discrete units, so you can save one while erasing the one before it. With tape-based systems, you have to erase all the messages at once.

Code-A-Phone's all-digital 6200 series machines even have color-coded messages. Green lights are empty message slots, orange lights are memos left by household members, and red are calls from the outside.



You won't find a tape inside Code-A-Phone's Model 6200 answering machine. It uses digital microchips to record both outgoing and incoming messages.

...the age of the digital answering machine

Digital technology, rapidly spreading to all branches of electronics, has reached the nearly ubiquitous telephone answering machine. Advantages: reliability, flexibility, ease of use, instant playback. Disadvantages to date: limited memory space and high cost.

By DAWN STOVER

instead of entering a security code to retrieve your messages remotely, you could just say hello to your phone.

Phone slaves

Add artificial intelligence to voice recognition, and you have what Christopher Schmandt, head of speech research at MIT's Media Lab, calls a "Conversational Desktop." Stewart Brand, author of *The Media Lab*, reports that Schmandt and colleague Barry Arons built the system in 1985. Brand describes a demonstration: A phone rings in Arons' office.

"Hello, Barry's telephone speaking. Who's calling, please?"

"Hi, this is Mike McKenna."

"What's this in reference to?"

"Your conversational messaging system," says McKenna.

"He's not available at the moment, but he left this message... (Barry's voice) I'm at lunch. I'll get back to you as soon as I return... (computer's voice) At what number can he reach you?"

When Arons returns to the office, his computer tells him he had a call and plays back McKenna's message.

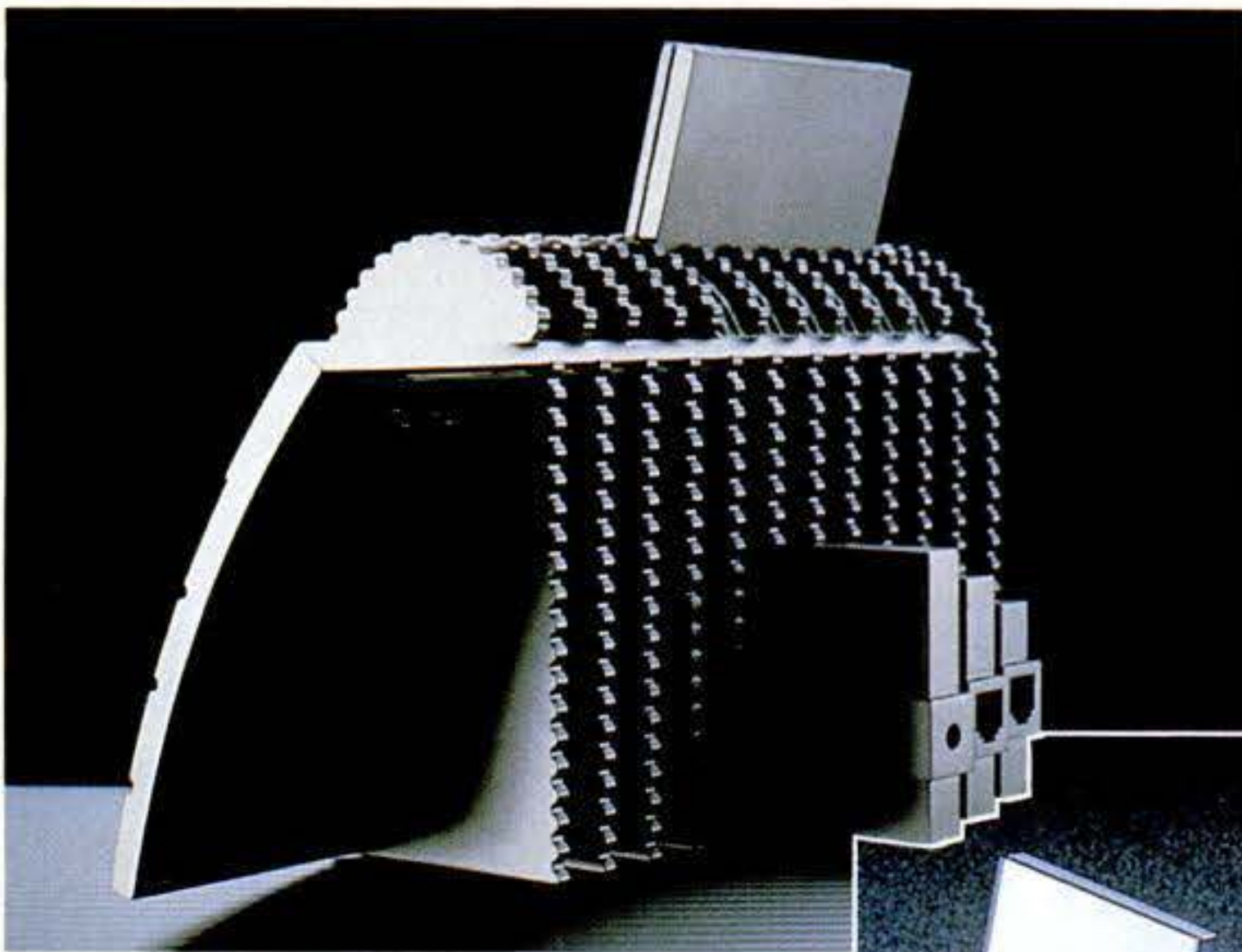
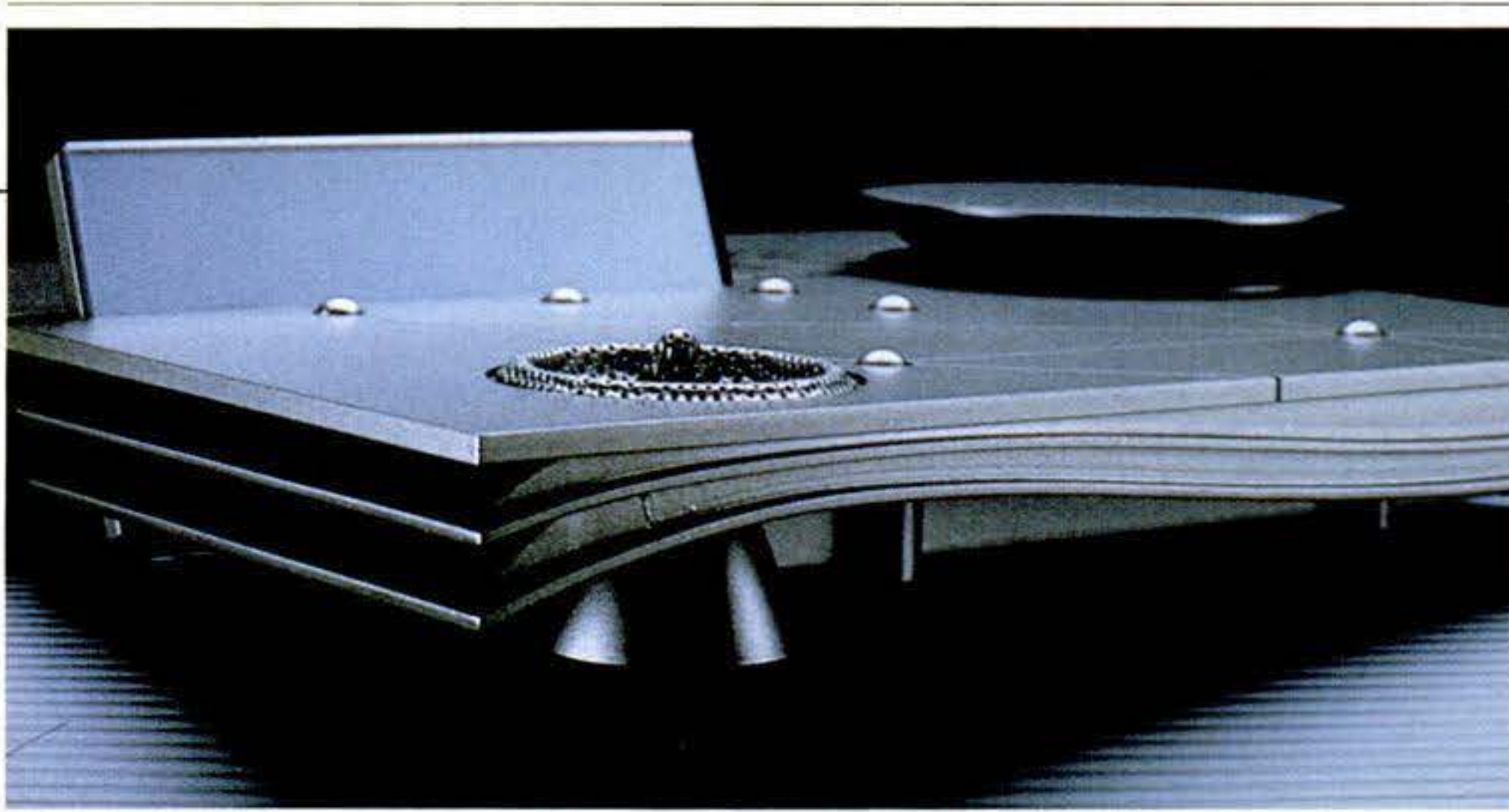
The Conversational Desktop, which Schmandt informally calls a "phone slave," can also identify some individuals at MIT, and Schmandt is teaching it how to route calls from these people. Some calls go to Schmandt, while others are forwarded to the answering system. Eventually, "smart"

Continued

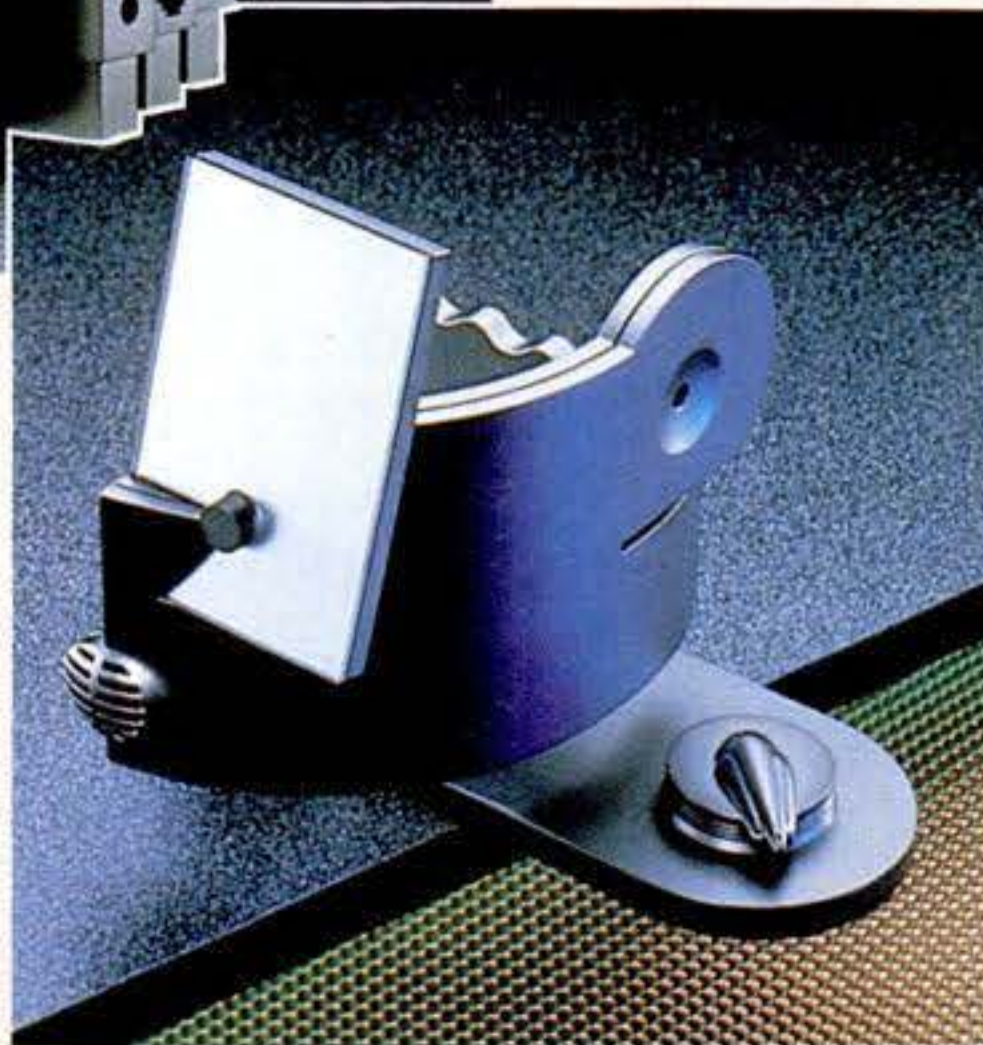
Digital technology offers other unexplored capabilities. It's now possible to change the size and shape of answering machines (see box). "When the technology becomes affordable," says Jim Oblak, director of marketing at PhoneMate, "there's no reason the answering machine couldn't be incorporated into a Trimline phone." A light in the handset could tell users that messages have been received.

Digital technology also simplifies the task of encoding and decoding messages, and it eases the development of voice-recognition systems. So

PHOTO BY JOHN B. CARNETT



Digital answering machines not only perform new functions, but also assume new forms.



COMING: THE ELECTRONIC MAILBOX

The earliest answering machines contained reel-to-reel tape recorders. "They were big, they were bulky, and they were not consumer machines," says Jim Oblak, director of marketing at PhoneMate. Replacing the reels with standard audio cassette tapes and microcassettes has enabled manufacturers to produce smaller and more streamlined consumer models, but the overall appearance of answering machines hasn't changed much in 30 years: They still resemble desktop tape recorders. About the only variation is a Panasonic machine that stands on end, with the controls on top. Even Code-A-Phone's all-digital machines haven't broken any new ground in design. But prepare for some radical changes. Now that answering machines no longer require tapes, unusual designs are feasible.

Dictaphone asked Design Logic, a Chicago firm, to come up with some alternatives to the flat box. "They said they would be using a completely digital technology," says Martin Thaler, a principal at Design Logic and one of the three designers who worked on the project. Dictaphone's main reason for hiring the firm was to stimulate fresh thinking among its own employees. Dictaphone currently has no plans to produce the designs.

Design Logic proposed three answering-machine models incorporating digital technology. The first one is the most traditional (top). "Most [answering machine] products are just flat planes with some controls on them," says

Thaler. Design Logic's creation also lies flat on a desk, but Thaler and his colleagues designed protruding parts to emphasize the elements of sight, sound, and speech. Buttons are located near the elements they control, not lined up along the front.

A second design (center) is an interpretation of a mailbox. "We thought that an answering machine was somewhat like a mailbox," Thaler remarks. "When you come home, you check your mailbox to see if you have any letters. You also check your answering machine to see if you have any messages."

The third approach (bottom) "establishes the answering machine as a mechanical/technological extension of a person," the designers explain. Planes and surfaces of the human head "have been abstracted and selectively used to create a surrogate 'self' to send and receive messages in the owner's absence," according to Design Logic.

"These designs may not be what consumers want in their kitchens," one analyst politely comments. Says Thaler: "If there is new technology, the machine should express it." —D. S.

home machines could also be programmed to recognize callers.

But digital-answering-machine technology has a long way to go before phone slaves show up on store shelves. Customers aren't clamoring for chips. "They're not concerned about what storage medium is used," says Robert Davis, product manager for answering machines at AT&T. "They don't care what's under the hood, just what it can do."

Sharp Electronics, which had introduced an all-digital answering machine, withdrew it from the market. Several other companies that previewed all-digital products more than a year ago still haven't begun producing them.

Record-A-Call makes a variety of tape-driven machines, but sells only one model with a digital outgoing message. "Sales on the 4000 have not been good," says Ristow. "It didn't fly."

Chip prices are holding the technology back right now. "They're prohibitively expensive," says Ristow. Chips are also in short supply, says PhoneMate's Oblak. With chips at a premium, manufacturers can't afford to build machines with a lot of memory. At one time, Code-A-Phone had planned to build a digital machine with a 10-minute memory, but has been forced to postpone the project.

"Recording messages is a memory-intensive operation," says Oblak. "Roughly every minute of conversation requires one megabyte of random-access memory." PhoneMate uses a 256-kilobyte chip to store the outgoing message in its digital machines. With a sampling rate of 16 kilobytes per second, the chip is filled in 16 seconds. Oblak says that 16K is the minimum sampling rate required to record a voice. But it's clearly inferior to the voice quality obtained with tape. "Your voice is *not* going to sound like it was recorded on a compact disc," says Oblak. Recording CD-quality sound would overload the memory almost instantly.

Code-A-Phone bumped up its sampling rate for the outgoing message to 34 kilobytes. Over the phone, it sounds as good as a tape. The sampling rate is slower for the seven incoming messages. Even so, they're limited to 16 seconds apiece.

The company's all-digital machines, which cost \$190 (\$240 with a built-in phone), were "intended to make a technology statement," says Lybeck. They appeal mainly to "telephiles," as one marketer calls them, buyers who understand the technology and are willing to pay extra for it. "Most people seem to have a conception that an answering machine is nothing more than a tape recorder connected to a phone," says Record-A-Call's Ristow. "Nothing could be further from the truth." **P 5**

One-hand clamp

For all of us who ponder, "Why didn't I think of that?" when we set eyes on a clever new invention, here's the story of a man who did.

By PHIL McCAFFERTY

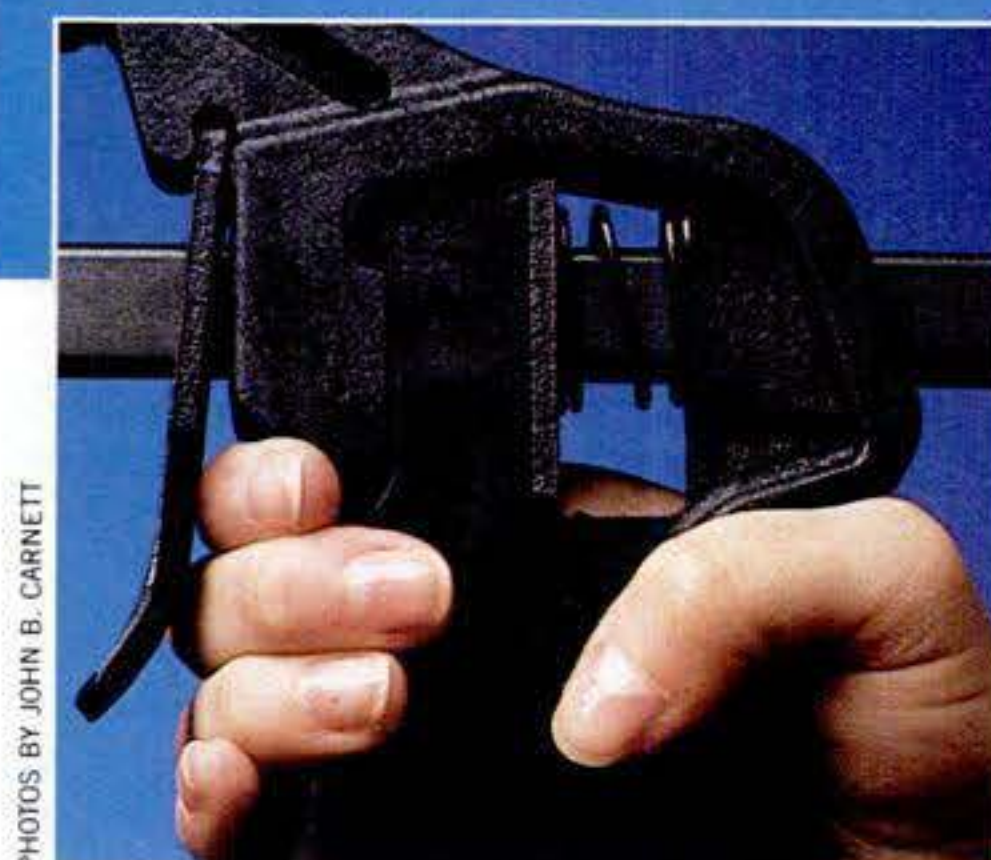
One day about two years ago, Joe Sorensen, a bearded young freelance artist from Lincoln, Neb., had a problem.

"I was making a project that called for gluing sheets of Lexan plastic together," he explained. "You know what happens when you screw a C-clamp down: The torque makes the sandwiched parts skid out of alignment. I muttered under my breath, 'Why hasn't somebody invented a clamp that can be operated with one hand so you have the other to hold the work?'"

Now someone has: Joe Sorensen. With the help of a friend, he designed a bar clamp you can operate with the squeeze of a fist. Better yet, the pair convinced a major toolmaker, American Tool Companies, to produce the clamp. And the topper: Sorensen is now the company's industrial designer.

The clamp, called Quick-Grip, grew directly (and rapidly) out of Sorensen's hassle with the Lexan project. Thinking maybe no one *had* invented such a thing, he contacted a tool-and-die-maker friend, Dwight Gatzemeyer. The pair sketched ideas, then proceeded to prototypes.

Next came a patent search. Incredibly, it seemed nobody had patented a device like theirs. So they packed up their samples and drawings and headed for American Tool Companies' plant in nearby DeWitt, Neb. (where Vise-Grip pliers and other tools are made). Soon Sorensen and Gatzemeyer had made a deal with American Tool.



PHOTOS BY JOHN B. CARNETT

The mechanism of the Quick-Grip bar clamp (above) can be seen when you pop off the logo plate, as at left: Two spring-loaded steel plates surround the bar; the front one extends to form the release lever (left of the operator's hand). When no pressure is applied to the trigger handle or release lever, the clamp can be pushed closed. Though the release lever is wedged against the bar, the forward push counteracts the force of the spring that holds it there. For one-hand use (or final tightening), you squeeze the trigger handle. A camlike action causes the rear slotted plate (lower left) to bind against the bar. This tugs the bar back about 1/4 inch with each squeeze. To open the clamp, you pull back on the release lever so that it is perpendicular to the bar.

No wonder the company was impressed. The clamp is an ingenious yet simple design. When you squeeze the trigger handle, the movable part of the clamp steps up the bar; when you release the trigger, two slotted-steel plates bind against the bar, locking the clamp in position. The photos and caption give the details.

The production clamp is made of tough, glass-reinforced nylon. The bar is black-oxidized, heat-treated steel. The clamp's grip is impressive: It will force a 10-penny nail through a 2x4,

for example. It comes in five sizes with 6- to 36-inch openings; prices range from \$21 to \$34.

Meanwhile, Sorensen started innundating American Tool with other ideas—on production details and new tool concepts. The company did the logical thing: It offered him a job.

So in just two years Joe Sorensen went from inspiration to successful inventor, and from freelance artist to American Tool's industrial designer. He and Gatzemeyer share in royalties from every Quick-Grip sold. **P 5**

An attic for all seasons

An innovative programmable air conditioner, an efficient gas-fired boiler, 10 inches of fiberglass insulation with special airflow vents above the ceiling. These and other new products help keep a third-floor family-room/study/bathroom addition comfortable no matter what the season.

By **TIMOTHY O. BAKKE**

Photos by John B. Carnett

Comfort should be a prime consideration in an attic renovation. Perhaps the most important factor contributing to that comfort is *sufficient* insulation.

Traditionally refinished attics have been notorious for overheating in summer and becoming bone-chilling in winter. I remember sweltering summer days and cold winter nights in the attic-converted bedrooms of my youth.

Today, by following new guidelines published by the U.S. Department of Energy, you can have cozy living at the top of your house. Just use the DOE-recommended amount of insulation—fiberglass, mineral wool, foam, or cellulose—to maintain a fairly even temperature spread and provide efficient heating and cooling backups.

Take the attic of Bob and Vicki Enteen. "When we decided to convert our attic into four badly needed rooms—a family room, extra bath, study, and storage room—I contacted the DOE for its newly revised insulation recommendations," Bob explained to me. "I wanted to make sure we could maintain a consistent temperature during both the heating *and* cooling seasons."

Enteen found that his New Jersey home was near a borderline zone where recommended ceiling values were R-38 or R-30. Local building authorities told him he had to insulate with unfaced fiberglass because of fire ordinances, but fiberglass would cut down headroom in the attic: Insulating to R-38 would mean using 12 inches of fiberglass; R-30 would use 10 inches. Enteen settled for R-30 to

minimize intrusion into the attic's headroom.

Moisture control

An important consideration with any insulation is preventing excess moisture, which can damage not only the insulation itself but a house's framing members as well. There are two ways to control moisture: installing a vapor barrier on the warm side of insulation and providing adequate ventilation to prevent condensation. Bob lined the living space with 4-mil plastic sheeting as a vapor barrier. To provide ventilation, he used an ingenious product, airflow channels from Poly/Molding Corp. These expanded polystyrene vents are 12 inches wide with a shallow U-shape. Stapled to the roof sheathing and running from the eaves to the collar beams that form the ceiling, the channels allow air to flow freely from the space above the flat ceiling through the eave vents.

Although insulation improves the thermal integrity of a structure, you still need environmental controls to make a living space comfortable from season to season. For light and air, the Enteens installed large casement windows and two roof windows, all double-glazed. For extra comfort on hot days, the Enteens chose to use a 12,500-Btu air conditioner with an energy-saving programmable thermostat. A new condensing gas-fired boiler provides baseboard heat for the winter. Using a secondary heat exchanger to wring out extra heat from combustion gases, the boiler reduces flue-gas temperature and brings its efficiency to 88 percent.

The Enteens paid close attention to the thermal performance of their ad-



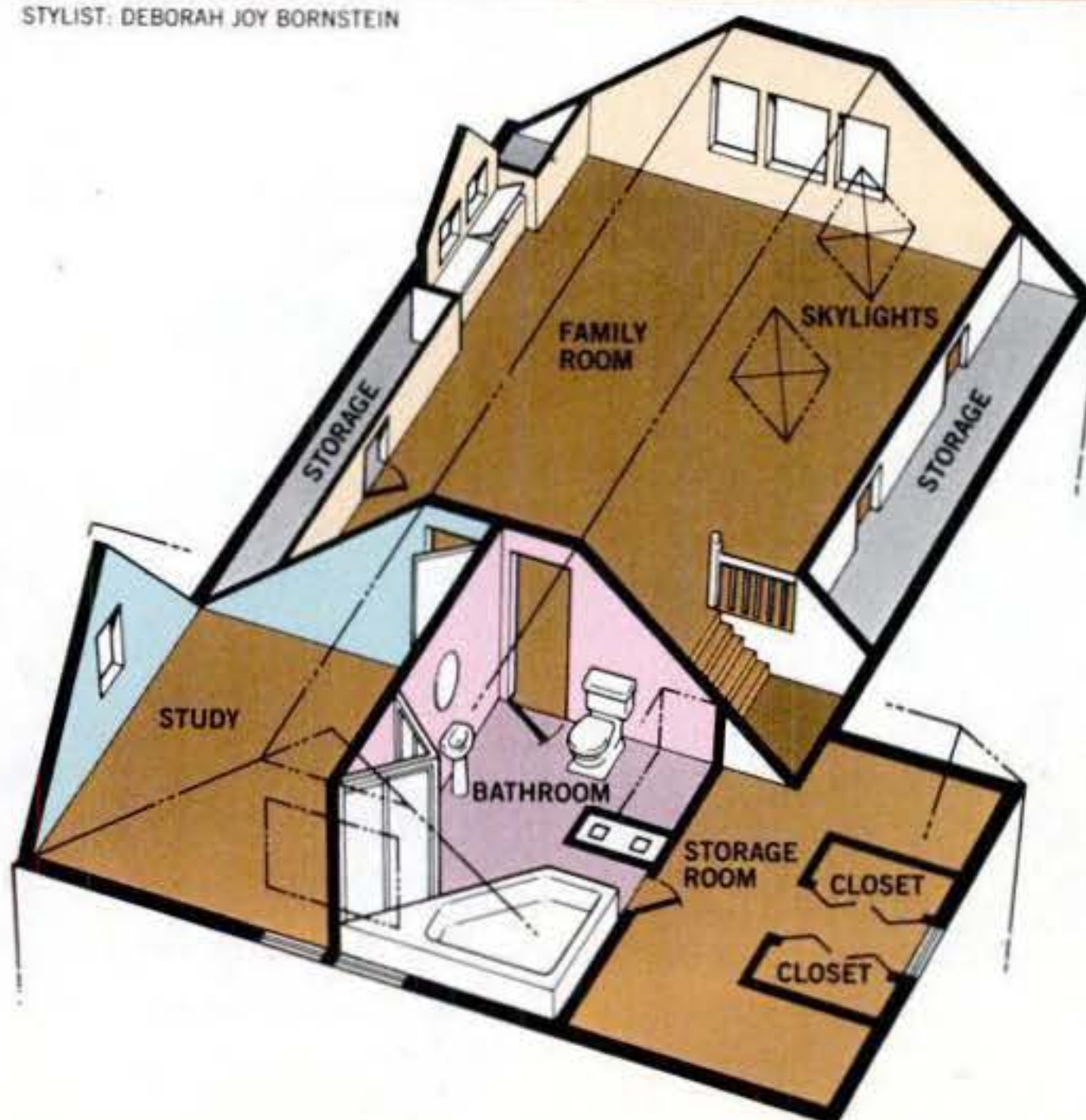
dition with the latest insulating and energy-saving products and technologies. Now they finally have their family retreat, a place where they can relax, read, watch TV, study, or work in comfort year-round. **PS**

MANUFACTURERS LIST

The following manufacturers were selected for participation in this project: **American Plywood Assn.** (plywood), 7011 S. 19th St., Tacoma WA 98411; **Florida Tile, Tile Council of America** (tile), Box 447, Lakeland FL 33802; **Harden Industries** (bathroom faucets, handles), 13915 S. Main St., Los Angeles CA 90061; **Hunter Fan Co.** (air conditioner with programmable thermostat), 2500 Frisco Ave., Memphis TN 38114; **Jacuzzi Whirlpool Bath** (whirlpool tub), Drawer J, Walnut Creek CA 94596; **Manville Corp.** (insulation), 717 17th St., Denver CO 80202; **Benjamin Moore and Co.** (paint), 51 Chestnut Ridge Rd., Montvale NJ 07645; **Poly/Molding Corp.** (airflow channels), Fourth Avenue, Haskell NJ 07420; **St. Thomas Creations** (lavatory, toilet), 9240 Trade Place, San Diego CA 92126; **H.B. Smith Co.** (gas boiler), Westfield MA 01086; **Thomas Industries** (lighting fixtures), Box 35120, Louisville KY 40232; **Tibbals Flooring Co.** (wood floors), Box 1001, Oneida TN 37841; **United States Gypsum Co.** (wall-board and related products, Durock tile backer board), 101 S. Wacker Dr., Chicago IL 60606-4358; **Velux-America Inc.** (roof windows), Box 3208, Greenwood SC 29648; **Wenco** (windows), Industrial Park, Mount Vernon OH 43050



STYLIST: DEBORAH JOY BORNSTEIN

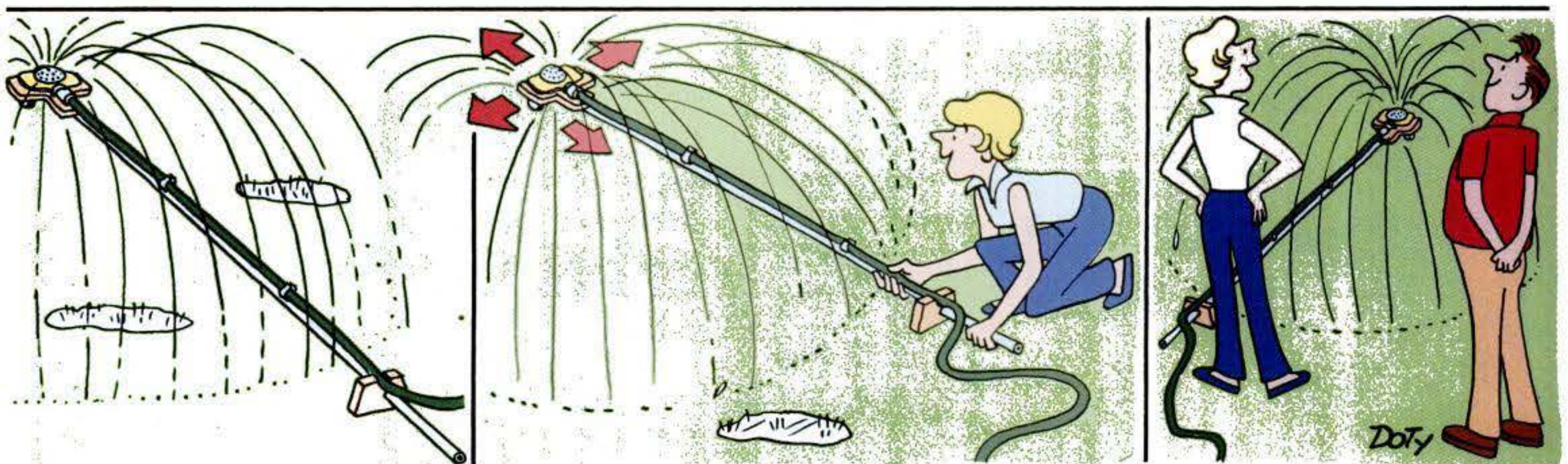
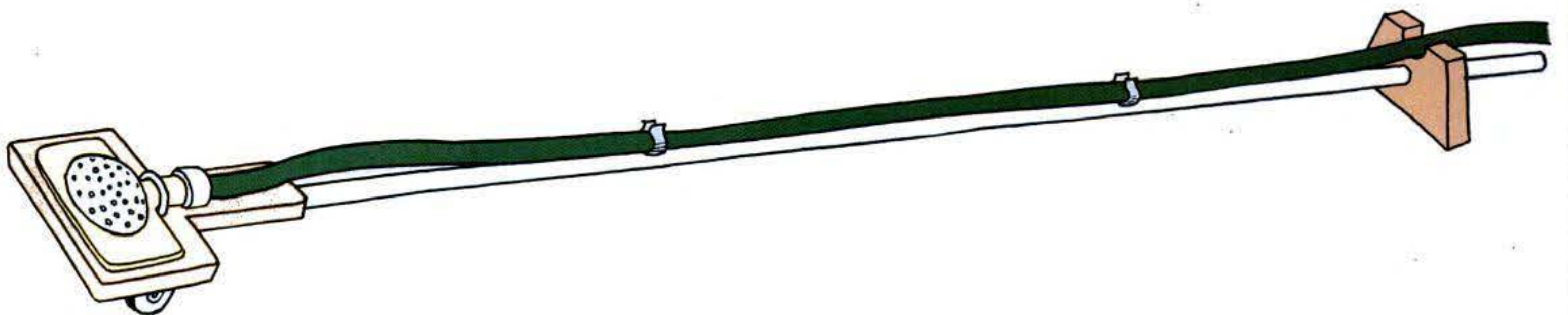
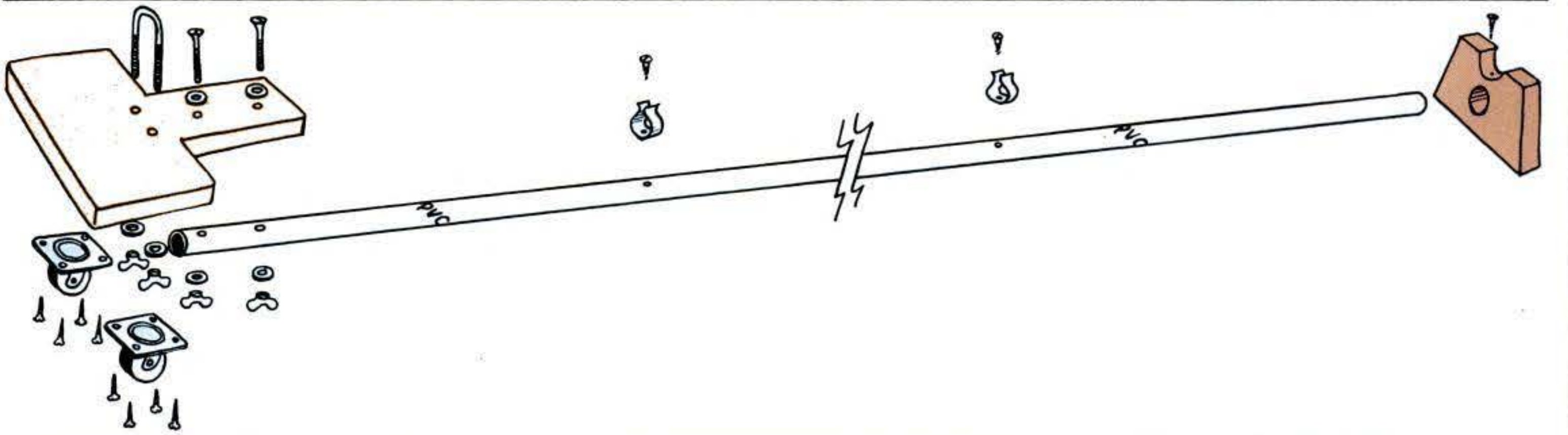
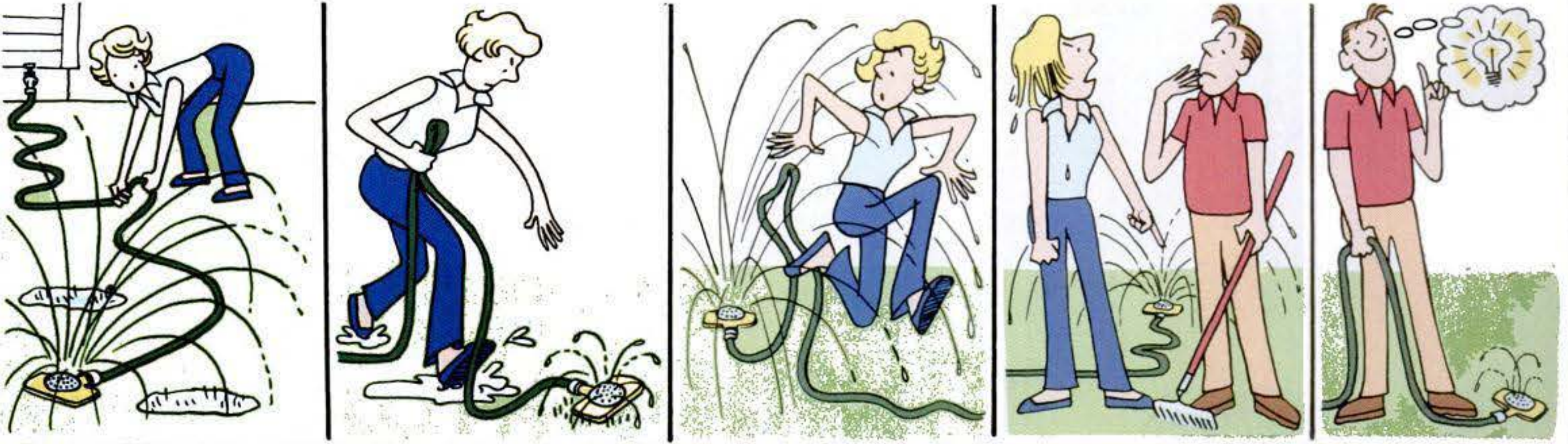


DRAWING BY EUGENE THOMPSON

Cozy family room is handsome—angular surfaces provide architectural interest—and heavily insulated. Venting roof windows help prevent overheating in summer; the supplemental air conditioner is large enough to handle the entire third-floor complex (left). Ample storage space is provided by knee-wall cabinets, where the TV and VCR are also concealed, and by a room built behind the bath. The bathroom (far left) is small but functional with a corner-hugging whirlpool tub and triangular shower.

Wordless Workshop

By ROY DOTY



\$50 to Tracy L. Sosa, San Jose, Calif., for this idea. Send yours (with Social Security No.) to Wordless, POPULAR SCIENCE, 2 Park Ave., New York, N.Y. 10016. Only purchased ideas can be acknowledged.

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APS-48

Readers Talk Back

Nuclear notes

I find it incredible that you consider it "a pity" to shut down a novel high-temperature gas-cooled nuclear reactor—even if it is the world's safest ["What's News," June]. Fission waste products have inherent safety and security problems. And there are better alternatives, like solar energy and conservation, to reduce carbon dioxide. The reactor's \$270-million cost over 14 years speaks for itself. The *real* pity is that even with federal \$1-trillion budgets, we can't rebuild slums, provide school lunches, and care for the hospitalized. Until everyone has the necessities, it's cruel to fund novelties.

Irving Newman, Beltsville, Md.

I disagree with the Sandia researcher's statement that electric bills for nuclear power doesn't pay for storing spent radioactive fuel or decommissioning old plants ["New Life for Solar?" May]. Many states include an allow-

ance for decommissioning in electric bills. And even if the cost of the federal waste-disposal program paid by utilities, the Nuclear Waste Fund, doubles—from the current 0.1 cent per kilowatt-hour to 0.2 cent—the average cost of nuclear-generated electricity would rise just three percent.

David Rossin, Los Altos Hills, Calif. (A former assistant secretary for nuclear energy at the U.S. Department of Energy, Rossin is an independent consultant on energy.)

Brain bender

Only at the end of "Hypermedia" [May] did you ask: "How will users find their way through this jumble of information?" We should focus more on user requirements for hypermedia-based tasks, rather than on the capability of the machines. Herein lies the challenge for human-factors engineers and cognitive scientists who, like me, study how people process and assimilate com-

plex information media—and apply this to system design.

Michael G. Samet
Integrated Systems Research Corp.
Woodland Hills, Calif.

Aluminum and Alzheimer's

The May "Science Newsfront" describes experiments with slurries of aluminum powder as rocket fuel. But the release of micro-particulate aluminum oxides into our atmosphere is potentially dangerous. Research increasingly implicates lifetime accumulation of ingested or inhaled aluminum as a component cause of Alzheimer's disease. I would consign aluminum fuel to the Moon and forbid Earth use.

Albert Sattin, M.D.
Richard L. Roudebush V.A. and
Indiana University Medical Centers
Indianapolis, Ind.

Address letters for this column to: Readers Talk Back, POPULAR SCIENCE, 2 Park Ave., New York, N.Y. 10016. We are unable to acknowledge unpublished letters.

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NEW LAB TEST REVEALS: SLICK 50 CAN CUT ENGINE WEAR IN HALF!

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WHAT IS POLY? "Poly" is short for polytetrafluoroethylene (TFE). It is the slipperiest substance known to man. **The 1988 Guinness Book of World Records (pg. 182) says:** "The lowest coefficient of static and dynamic friction of any solid is 0.02, in the case of Polytetrafluoroethylene - equivalent to wet ice on ice. It was first manufactured in quantity by E.I. duPont in 1943, and is marketed as Teflon™."

The PetroLun Corporation, makers of Slick 50, have invented a way to permanently bind "Poly" to your engine with one treatment. All you do is add one quart of Slick 50 to your oil. By reducing engine friction, Slick 50 increases gas mileage and horsepower and it reduces engine wear, defraying costly overhauls.

Slick 50's credentials are impressive.

Just this year the premiere engine and lubricant testing lab in the U.S. tested Slick 50. This EPA approved lab conducted a strictly controlled experiment using industry standard ASTM procedures. They found that engines whose oil had been treated with Slick 50 showed **52% - 57% less engine wear** than engines whose oil had not been treated with Slick 50. We know of no other Poly treatment on the market that has passed a wear reduction test conducted by an EPA approved lab using nationally accepted ASTM procedures. Watch out for those treatments that cannot back up their claims with such solid evidence.

"Slick 50 does reduce engine heat and ordinary wear, and our informal tests indicate that it will improve gas mileage by about two or three miles per gallon...Slick 50 does exactly what PetroLun claims it does." Consumers Digest, (March/April 1982, p. 35)

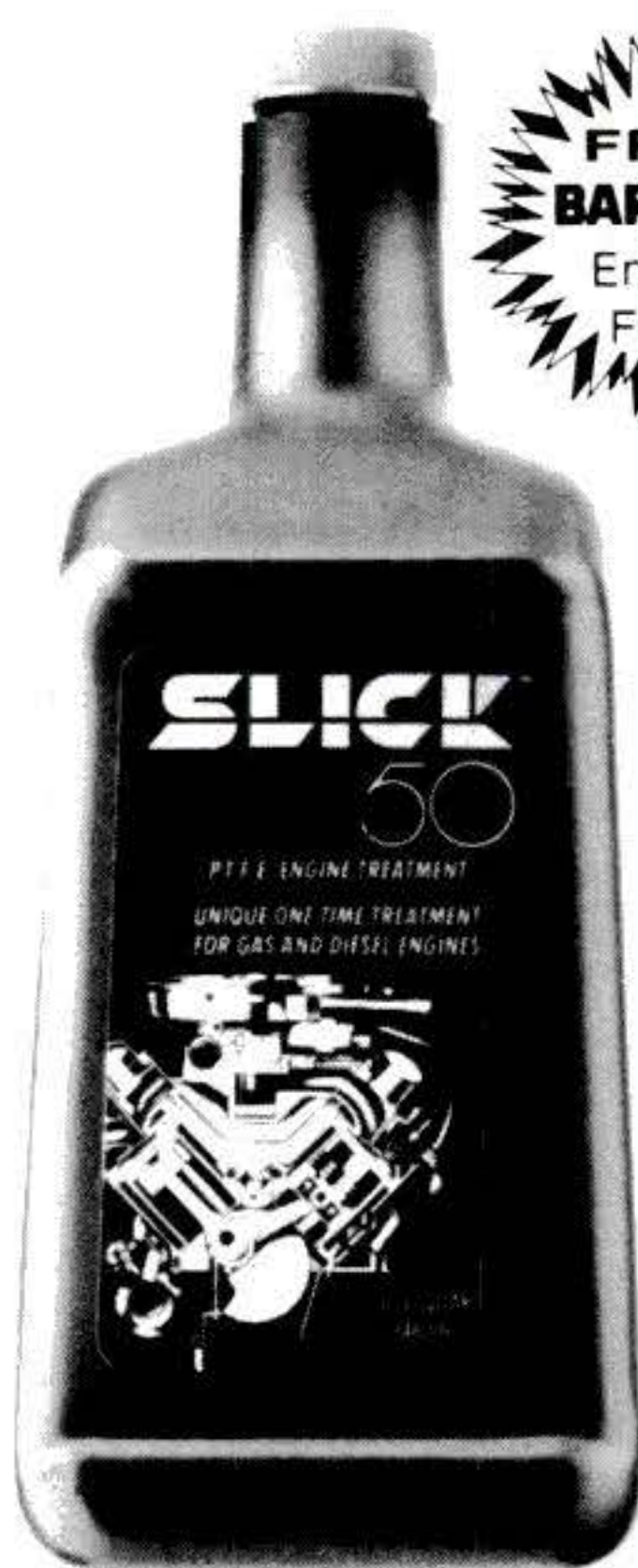
Researchers at a **nationally respected research laboratory**, after applying a powerful ultrasonic cleaning process to a Slick 50 treated engine part, were surprised at its permanence. They stated, "We actually expected the PetroLun Slick 50 "Poly" resin coating to also be removed, but later found it was still there."

The **Federal Aviation Administration** has fully accepted a similar product - Slick 50 Aircraft Treatment (F.A.R. #33.49).

TUV, a German testing laboratory with credentials every bit as prestigious as our Underwriters Laboratories, tested Slick 50 in 1986. They found substantial increases in both gas mileage and horsepower.

A test done at the **San Diego State University** revealed that, "Slick 50 does increase horsepower and decreases fuel consumption in tests done at the university." The **Space Shuttle Columbia** uses the chemical "Poly" in its gears and bearings because it is the only chemical lubricant which can withstand the heat and corrosive elements of space.

Perhaps the most dramatic of all is a torture test overseen by the Automotive



Services Council for Pennsylvania. This test was shown on television station WTVE. Three cars with between 75,000 and 129,000 miles on them, were treated with Slick 50. Six months later the oil was drained from each vehicle and the cars were driven without the oil plugs for about half an hour. The water temperature never rose and the engines sustained no apparent damage.

How do you give an engine a "Poly" treatment? Very simply! Add your **FREE Bardahl** flush and idle engine for 10 minutes. Then change oil and filter and substitute one quart of Slick 50 for the last quart of oil. (Add two quarts for engines with oil capacities of seven quarts or more.)

Slick 50 gives a permanent coating so you need to treat your engine only once, and not each time you change your oil. Slick 50 is also excellent for turbocharged engines, aluminum block engines and rotary engines.

Slick 50 will work with all petroleum based oils and synthetics compatible with petroleum based oils.

What are the benefits of Slick 50? Since there are many factors that influence an engine including the type of driving, temperature, engine condition, oil change intervals, etc., the actual benefits in percentages will vary. However, by reducing friction, Slick 50 does all of the following: Slick 50 **increases gas mileage**. Slick 50 **increases horsepower** - small economy cars and large RV's really need this! Slick 50 **makes for easier starting** (important in cold weather.) Slick 50 **reduces operating temperatures**, thus increasing the lubrication of your oil and the life of your engine. Since lubricating lead is being removed from gas, and unleaded gas is poor in lubricating qualities, **this extra lubrication of**

Slick 50 on valve systems and guides is a real bonus.

Last, but not least, the drastic reduction in engine wear can delay costly overhauls. These can often cost well over \$1,000. Slick 50 eliminates the "lubrication starvation" that all cars experience when you first start them, before the oil has a chance to circulate. Up to 90% of engine wear can be caused by this starvation. You receive all these benefits for less than the cost of two tanks of gas (\$39.95).

Will Slick 50 harm my engine or affect my warranty? No! The base oil for Slick 50 meets, or exceeds, every manufacturer's engine warranty requirements and carries an API service classification SG-CD.

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CAR-CARE QUIZ

This month's auto-repair puzzlers: an overheating auto with a homeless spring, a distributor cap that keeps blowing its top, as well as a car that insists on going left. See if you can solve these perplexing problems. The answers follow.

By **STEVE MERCALDO**

Drawings by Russell von Sauer

Problems

1 Mystery spring

My neighbor is a do-it-yourself auto mechanic who keeps the family cars in top-notch condition. One lazy Sunday afternoon the phone rang. It was his wife, and from her tone, he knew it was trouble. She said she had been driving along the highway when steam began to pour from under the hood. She pointed the car toward the shoulder, braked the car, and shut off the ignition.

His wife had waited in the car for the better part of an hour when a passing motorist stopped and asked if he could lend a hand. Popping the hood open, the good Samaritan scanned the engine compartment and found a ruptured upper radiator hose. He told her that he couldn't fix the hose, but that he could drive her to a telephone.

After speaking to his wife, my neighbor jotted down the directions, filled a jug with water, grabbed a tool kit, and drove to the scene with the jug in the trunk.

Peering under the hood, my neighbor saw that his wife's helper had been correct: The upper radiator hose was torn. My neighbor patched the hole with electrical tape and filled the radiator with water. To prevent pressure buildup inside the radiator, he set the radiator cap in place, but left it loose. When he was certain that the system was holding water, he and his wife headed home in the two cars.

When he returned from work the next day, my neighbor was greeted with a pleasant surprise. Lying next to the ailing car was a pile of used radiator hoses and clamps. Earlier that day his

son had removed the old hoses and installed a new upper and lower radiator hose, heater hoses, and a bypass hose. The youth was pouring a fresh charge of antifreeze into the radiator. Once it was full, my neighbor started the engine and allowed it to warm up as his son topped off the system with water. As the engine idled, father and son inspected the cooling system. There were no leaks.

While his son went inside to clean up, my neighbor spotted something odd as he discarded the old hoses. A shiny new coil spring was mixed in with the worn and dirty hose lengths. The spring measured about two inches in diameter and about 16 inches long. It didn't look as if it had come from the engine. He wondered how the mystery part got into the refuse pile.

When questioned about the spring, his son said that he had found it in the box of new hoses and clamps he'd purchased. He guessed that the auto parts clerk had mistakenly dropped the spring into the box. He was certain that the unexplained spring did not belong in the cooling system because he hadn't taken an old spring out.

For about a week the car worked well. Then my neighbor's car overheated, and his wife was stranded again.

When he opened the hood this time, he saw no signs of a leak. In fact the cooling system recovery tank was only a little short of coolant. His wife explained what had happened: Within a few miles after getting onto the interstate, the temperature gauge light on the instrument panel registered "hot." To avoid a repetition of the last episode, she immediately pulled to the side of the road and shut off the engine.

Starting the engine, my neighbor watched the temperature indicator. When it failed to light up after 10 minutes of idling, he decided to drive the car home. His wife followed.

As he drove, my neighbor monitored the temperature indicator light. It remained dark at low speeds, but as soon as he began to accelerate, the light came on. Could the light be faulty? Maybe the thermostat is defective. Or perhaps the radiator is clogged? He was sure that the cooling system was not leaking fluid. He decelerated the auto and crawled back to the house.

Rather than replace more parts, my neighbor did some trouble-shooting. He removed the thermostat and placed it in a pan of cold water. Then he put a thermometer in the pan and set it over a hot stove. Knowing that the thermostat was rated at 190 degrees F, he waited as the temperature rose. When the water temperature reached the rated temperature, he saw the thermostat valve open. After removing the thermostat to cool, the valve soon closed. My neighbor then moved on to the next possible cause, the radiator.

The radiator's exterior looked fine. Its fins were free of debris. Inspecting the interior of the radiator presented a problem, however. The exposed core tubes visible through the filler neck seemed clear, but it told him little about the tubes hidden inside. Rather than take a chance, he removed the radiator and brought it to a radiator shop for a boil-out job.

Hoping that he had the problem solved after the radiator was reinstalled, my neighbor tested the car once more on the road. Within a mile of reaching cruising speed, the instrument-panel temperature indicator lit up. He pulled the car over to the side and lifted the hood while listening to the familiar crackling sound of a hot engine.

Flashlight in hand, he looked the engine over: The recovery tank was full, but the coolant was gurgling noisily. In addition, the electric cooling fan was spinning like a windmill in a storm.

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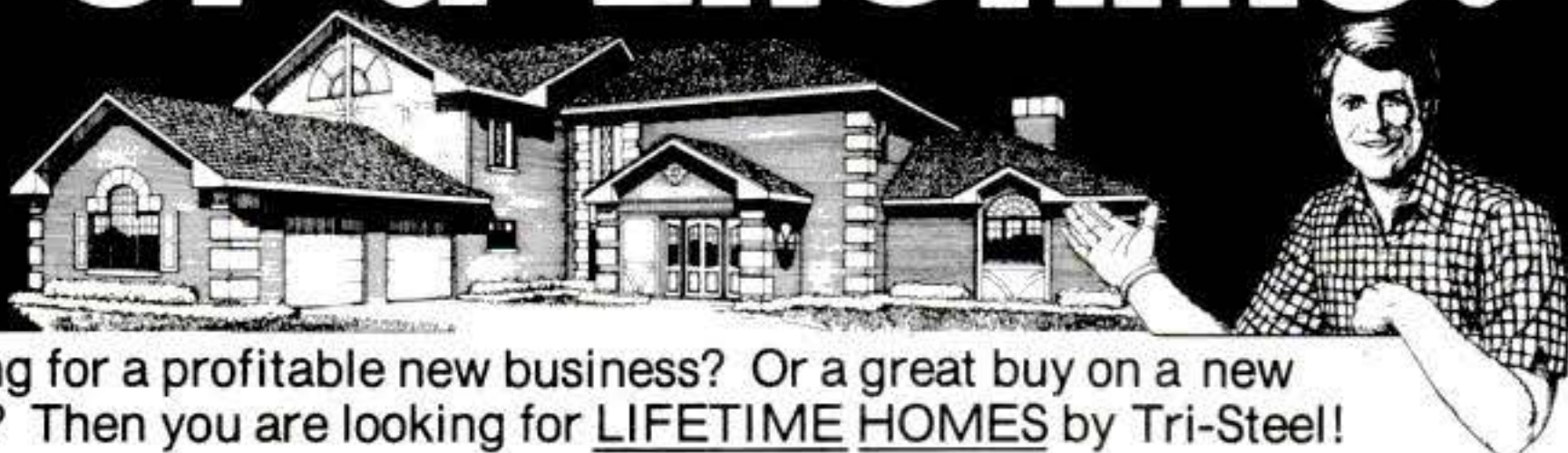
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Car care quiz *Continued*

After about 25 minutes the hot engine settled down, and my neighbor restarted the engine. While he was watching the instrument-panel temperature light, he let the car idle. Two minutes passed when the light began to glow red once more. He switched the ignition off and looked under the hood again. The coolant's gurgling and the crackling of the hot engine continued.

Once again he allowed the engine to cool off and then restarted the engine. This time he grasped the throttle under the hood and revved the engine. Within a few moments the engine showed signs of overheating. At this point he knew he had a few seconds to search for the problem before the motor cooked. While maintaining the high speed, he noticed that the lower radiator hose had totally collapsed. As soon as he released the throttle linkage, the hose popped back to its original shape.

Why is the engine overheating at high speed?

2 Pop-top distributor

For several minutes the sound of the starter motor in your neighbor's 1976 AMC Hornet filters into your kitchen. It seems strange that she continues to crank the straight-six engine even though it won't turn over. You wait for the starter to burn up or for the battery to go dead. The battery loses out.

Minutes later your neighbor knocks at your door and asks you to start her car. She assures you that the problem is a simple one that can be remedied quickly.

As soon as you pop the hood, the reason for the non-starting engine is obvious: Lying off to one side of the distributor is the distributor cap. The high-tension cable is still connected.

When you point out the dislodged cap, she explains that twice a month the car refuses to start because the cap is off. With the cap reattached and the battery recharged, you fire up the engine. Your neighbor thanks you and drives away.

During the next few weeks the scenario reoccurs. Tired of reinstalling the cap, you attempt a permanent fix. Armed with some hand tools and a repair manual, you begin with a visual inspection that reveals no cracks. You then attempt to jar the cap loose, but it doesn't budge. Satisfied that the retaining clips are holding the cap tightly, you look elsewhere.

Thinking that a bent distributor shaft or a worn bushing is allowing the spinning rotor to knock the cap off, you remove the cap and get your neighbor

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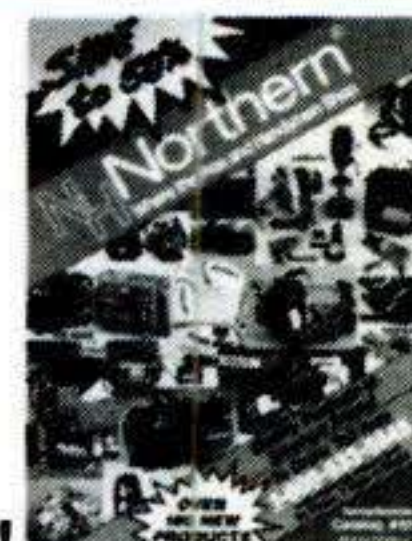
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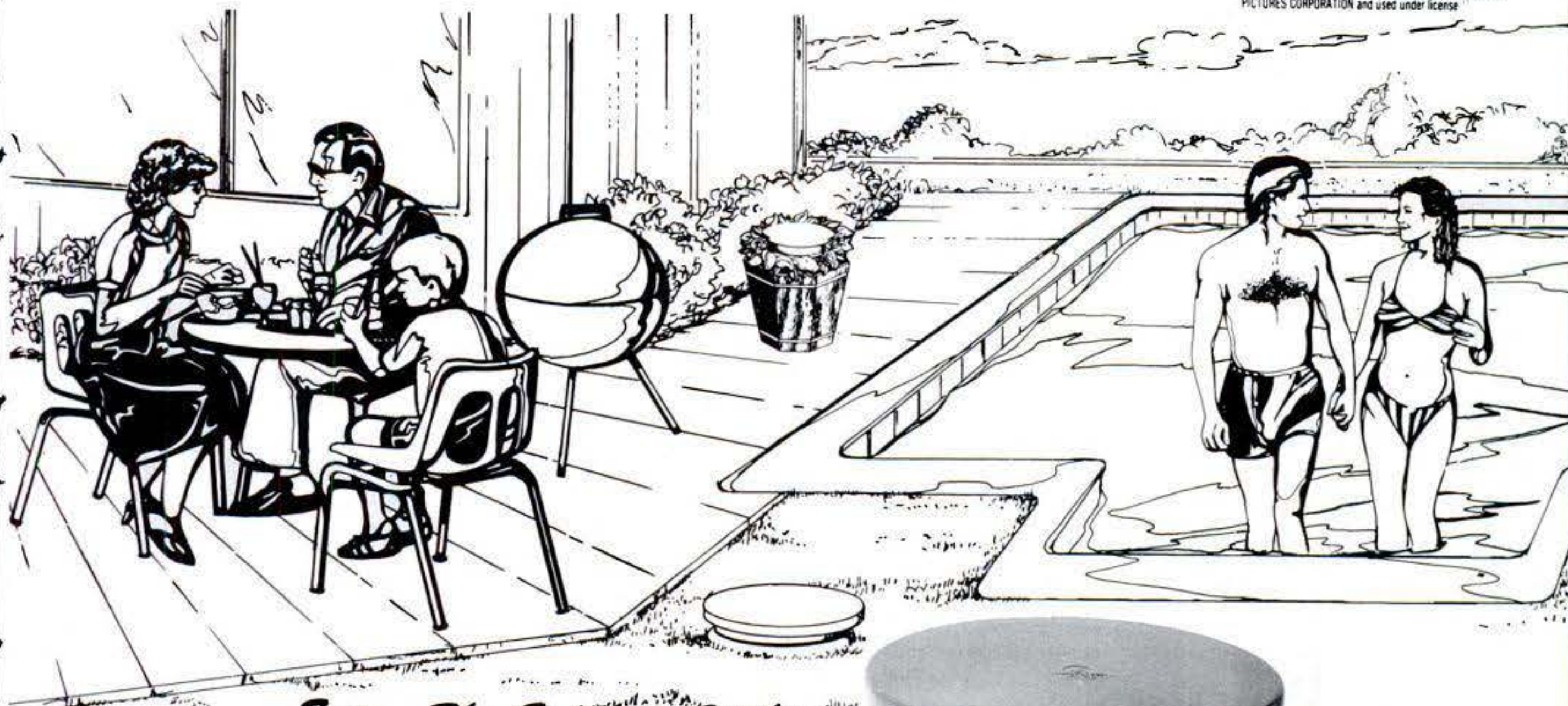
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Car care quiz *Continued*

to crank the engine. The shaft spins true in its slot. After she turns the engine off, you grasp the rotor and try to move the shaft from side to side. There's little sideways play.

Then you follow the repair manual for fault-checking the distributor's electronic-ignition components:

The trigger wheel is fixed tightly to the shaft, and the pickup coil is fastened to the housing. The clearance between the trigger wheel and the pickup is right on specification.

Testing the timing is the next logical step, you decide.

The repair manual says the ignition timing should be at five degrees before top dead center (BTDC) at idle speed. At high rpm the timing should advance to between 35 and 37 degrees BTDC.

After connecting a timing light and a tachometer to the engine, you set the idle speed to the timing rpm. With the vacuum-advance hose disconnected and plugged up, the timing is on-target at five degrees BTDC. You reattach the advance hose to the distributor and accelerate the engine to the test speed. At 2,200 rpm, the timing mark moves about 15 degrees BTDC. The book says that's not enough.

You figure that your next step is to remove the vacuum-advance unit hose to feel for suction at the hose end as your neighbor hits the gas. A strong vacuum sucks on your hand at the off-idle speed. Your neighbor maintains a fast idle while you quickly reconnect the hose. As the hose attaches, the engine speed remains constant.

At this point you realize that you've exhausted your limited knowledge of the problem, so you kill the ignition, remove your tools, and close the hood. After washing up, you climb behind the wheel and start the engine. A small pop comes from under the hood, followed by the familiar sound of the starter. You climb out and open the hood. Sure enough, the troublesome distributor cap lies next to the body.

Convinced that the cap is defective, you buy a new one and install it. For a week the car starts and runs fine. Then you hear the Hornet cranking away again and your neighbor soon shows up at your doorstep holding the distributor cap.

What could be causing the cap to pop off?

3 Left-pulling car

You're in the market for a used car. From the newspaper classifieds you find one that looks promising. "1985

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Car-care quiz *Continued*

Chevrolet Camaro, ps/pb/as/at, new tires, showroom condition, 58k..."The price seems right, so you decide to check it out.

A visit to the owner reveals a car with an engine and body in super shape. The engine runs smoothly, doesn't blow smoke, and sounds tight. On the road, the engine accelerates well, the transmission shifts without slipping, and the car is free of any unusual sounds. You do notice, however, that the car pulls to the left a bit when it's driven on a level road. Confident that the pull does not constitute a major problem, you purchase the automobile.

Several weeks later you see that the outer treads on the left front tire are worn. The other tires show normal wear. Concerned about the rapid and uneven tread wear, you decide to investigate.

You begin by checking cold tire air pressure. Unevenly inflated tires can cause a car to pull to one side. When you check the left front tire with a gauge, the pressure is at the right level.

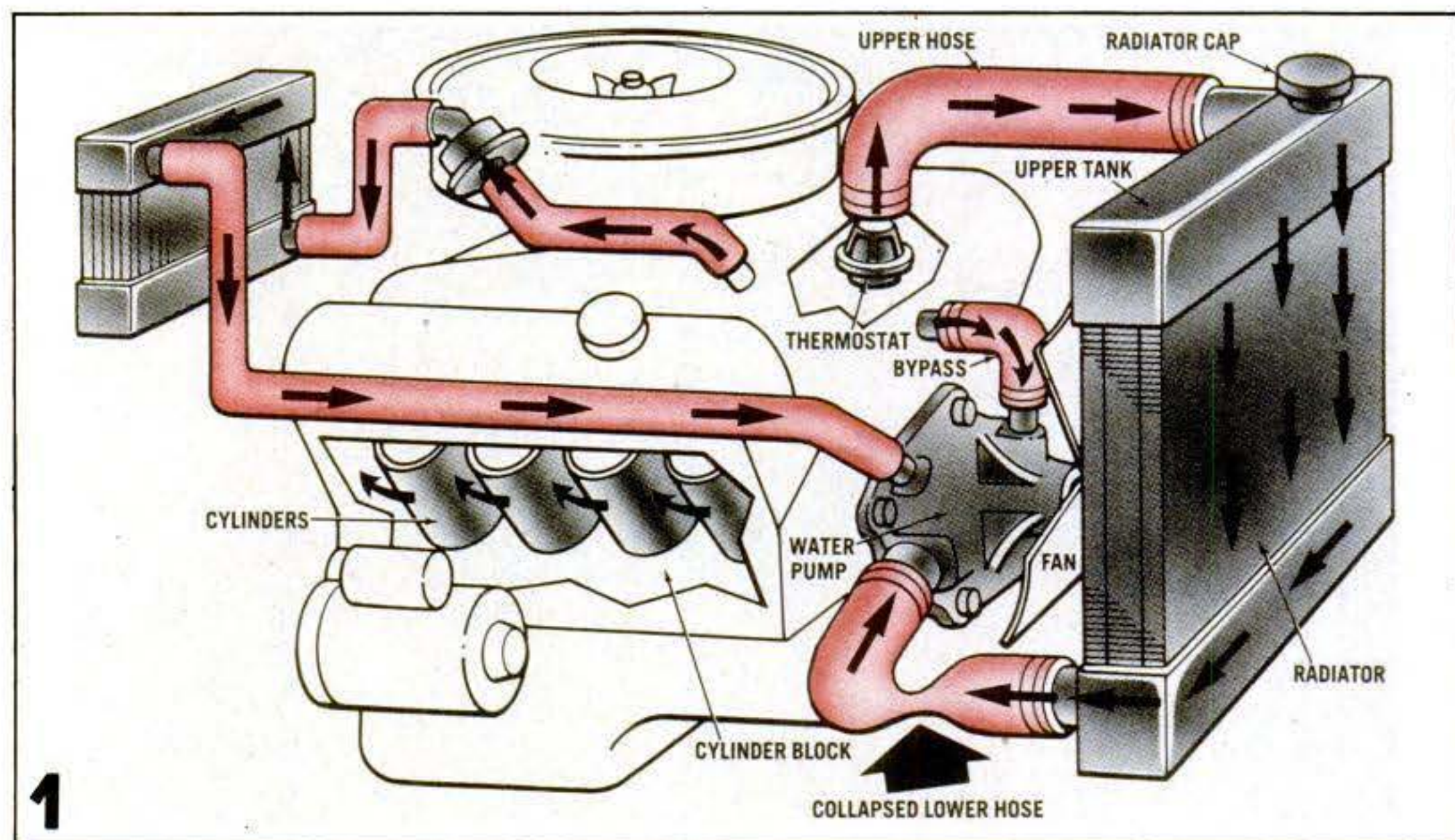
Next you look to see if the left front tire is smaller in diameter than the one on the right. Comparing sidewall labels, you determine that all four radial tires are the same brand and size.

Maybe a tire belt has slipped and is causing the car to pull. To rule this out, you switch front tires and road test the car. It still pulls left.

It seems possible that a dragging brake could be the culprit, so you turn your attention to the brake system. You jack up the car and support the frame on safety stands to provide more working room. You pump the brake pedal several times and then manually spin each wheel. The fact that each wheel spins freely eliminates the possibility of a binding caliper or wheel cylinder. The free-spinning wheels also exclude the chance of a worn or unlubricated bearing.

Just to be sure, you remove the wheels and inspect the brake system. The inspection reveals that the calipers and wheel cylinders are not leaking. Drums, rotors, pads, and shoes also check out OK. Then you test the parking brake. When engaged, the parking brake locks the rear wheels. When you pull the release handle, the wheels spin free. You then move on to the power-steering mechanism.

With the car still supported on jack stands, you start the engine and turn the steering wheel to the straight-ahead position. You find that accelerating the engine does not cause the steering wheel to rotate. This means that the pull is not being caused by a faulty power-steering control valve. Now you wonder whether a worn or damaged front-end component is caus-



ing the car to veer over to the left.

With the frame jacked up, you check for a loose ball joint or other suspension part by grasping the left front wheel at the 12 and 6 o'clock positions and attempt to rock the wheel in and out. Everything feels tight. The right side checks out also.

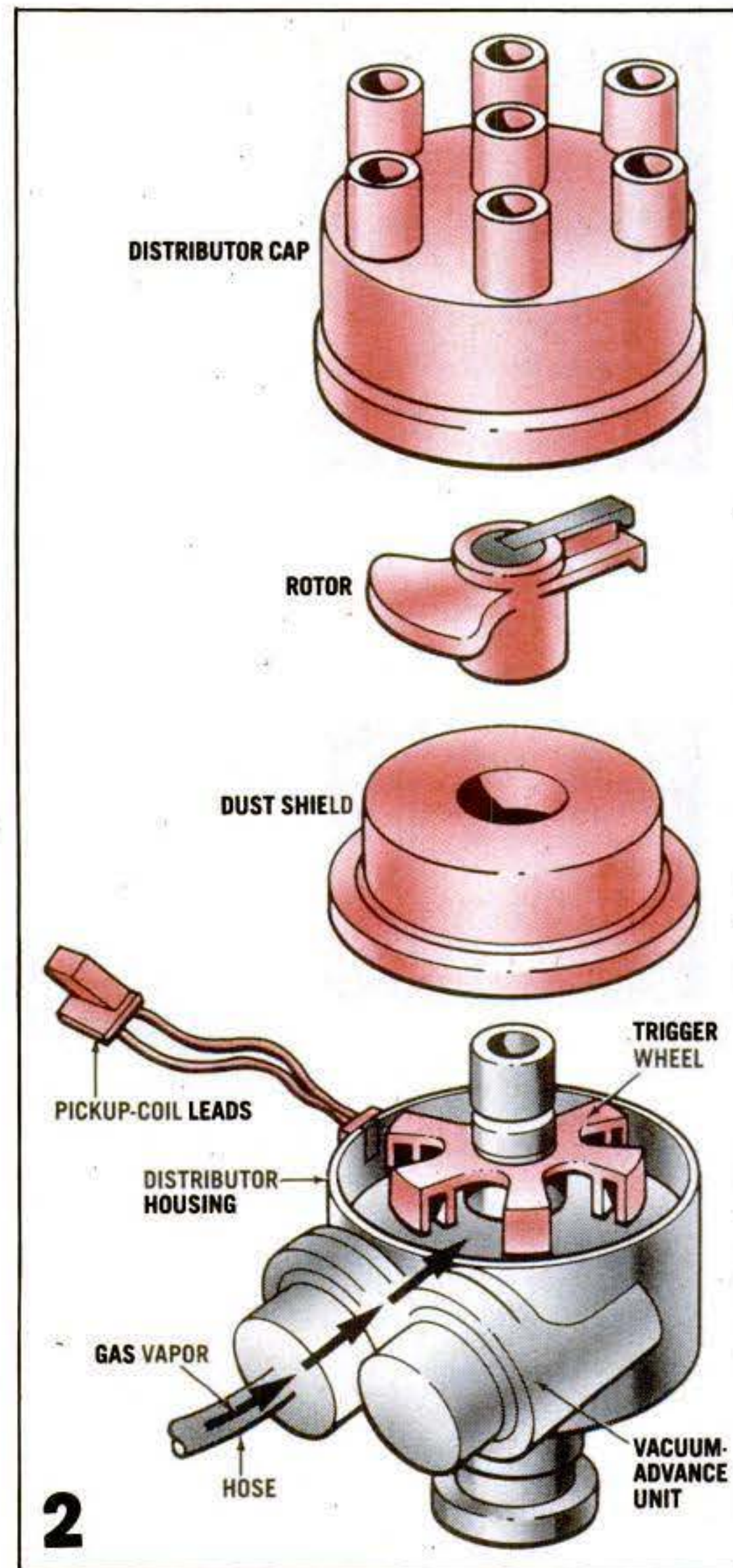
On this car the front coil springs are positioned between the frame and lower control arms, as are the shock absorbers. A careful inspection reveals that the springs are unbroken and seated in their normal position on the frame and the lower control arms. The shocks are not loose and are free of leaks. On to trouble-shoot the next possible cause—steering linkage.

An examination of the idle arm, pitman arm, center link, and tie rods shows that the steering system components are in good shape. When you test them manually, you find no up-and-down looseness. Even the steering-gear mounting bolts are securely attached to the frame.

Fearing improper alignment, you decide to take the car to a front-end specialty shop and have the front wheels aligned. When you arrive at the shop, you tell your tale to the mechanic, noting that you've checked the front end, adding that a simple alignment should do the trick. You are taken back a bit when the mechanic begins by rechecking the suspension for wear, despite your warnings that he's wasting his time. He checks for the proper curb height and continues by placing a jack under the lower control arm. Jack in place, he lifts the car.

When he grabs the left front tire at the top and at the bottom and rocks it back and forth, you're really surprised. You can see the wheel move in and out. The mechanic suggests you watch the lower left ball joint as he moves the wheel in and out vigorously.

It doesn't take an expert to see that the ball joint is moving in and out more than a quarter of an inch. The remaining ball joints test out fine. The mechanic explains that the worn ball joint must be replaced before an accurate alignment job can be performed. He guarantees that if you follow his advice, the abnormal wear of the tire and



the leftward pull will be corrected.

Puzzled, you assure him that when you checked the front end for wear, the lower left ball joint was snug. How did you miss spotting the loose ball joint?

Solutions

1 The unexplained coil spring that my neighbor found in the pile of used parts belongs inside the new lower radiator hose. Its function is to prevent the lower hose from collapsing inward under high suction. The reason his son did not recognize the homeless spring is because its counterpart in the old, worn lower hose was molded into the hose walls.

Why does the lower hose need the spring to prevent collapse? The inlet to the water pump is connected to the radiator by the lower hose. Coolant entering the pump must first pass through the hose. At low speed, pump suction is minimal. At high speeds the pump impeller blades create a strong suction force in the lower radiator hose. Without support from the spring, the hose collapses, blocks the coolant flow, and the engine overheats.

2 A ruptured diaphragm in the distributor vacuum-advance unit is causing the cap to dislodge when the car is started. Fuel vapors from the intake manifold or carburetor are leaking through the diaphragm and collecting under the distributor cap. When the engine cranks, the high-tension spark that normally jumps from the rotor tip to the cap lug ignites the vapor. The resulting small explosion blows the cap off the distributor. Replacing the vacuum-advance unit eliminates the recurring problem.

The clue: As the engine was accelerated, ignition timing advanced only 15 degrees BTDC. The manual specified a maximum advance of between 35 to 37 degrees BTDC. You felt a strong vacuum at the end of the vacuum-advance hose. This eliminated the possibility that no vacuum was getting to the unit. And when the hose was connected to the unit, the engine revs remained constant. If a vacuum-advance unit is working, engine speed will increase as the advance unit moves the distributor base plate and advances the spark timing. The 15-degree change recorded as the speed increased was caused by the mechanical-advance weights. A further examination of the advance unit with a

hand-operated vacuum pump should verify whether a vacuum advance unit is faulty.

Note: If the new vacuum-advance unit fails prematurely, replace it once more, but this time install a liquid-vapor separator in the vacuum hose. This aftermarket device will prevent fuel vapors from entering and destroying the new vacuum-advance-unit diaphragm.

3 You missed the worn ball joint because you supported the car's suspension improperly when you performed the front-end check.

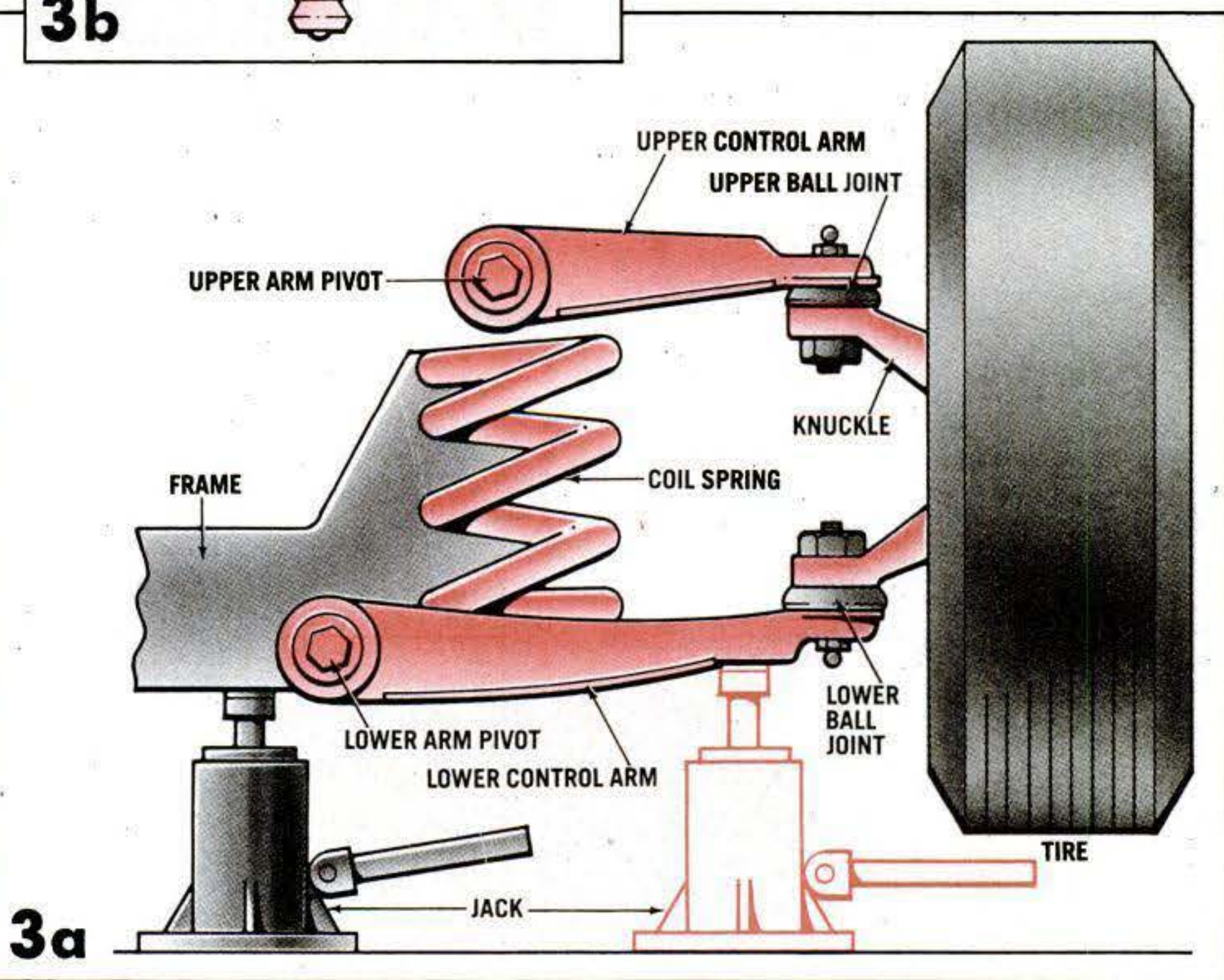
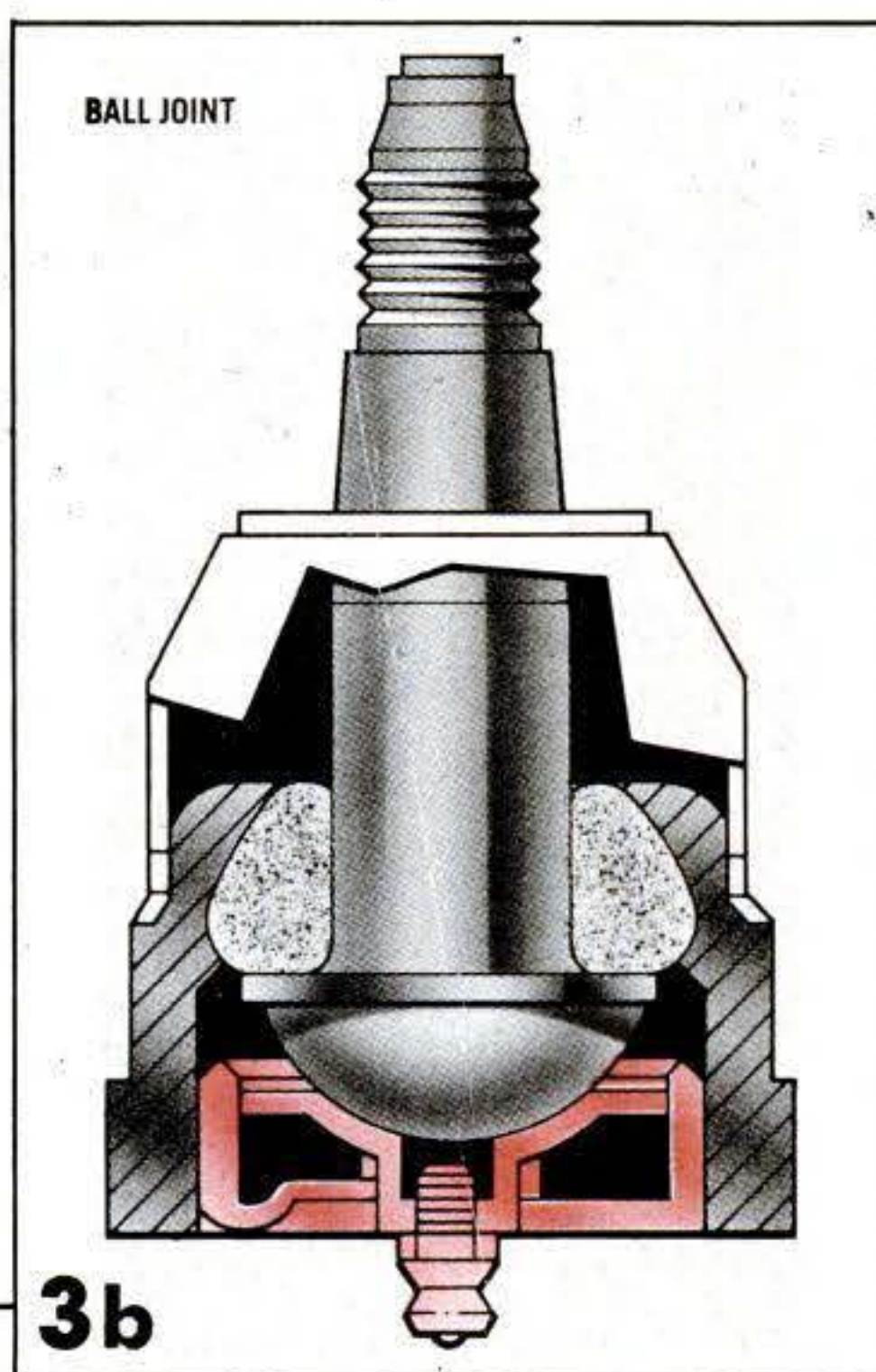
Here's how to jack up a vehicle prop-

erly: When the coil spring is located between the lower control arm and the frame—as it is in this case—the jack or safety stand must be placed under the lower control arm close to the tire. This position unloads the ball joints and the upper control-arm bushings. That's because the correctly placed jack compresses the spring against the frame and relieves the tension on the other parts. This technique also applies to vehicles that use a torsion bar instead of a coil spring. If the torsion bar connects to the lower control arm, jack under the control arm to unload the suspension, and then check for wear.

If the coil spring is mounted between the frame and the upper control arm, jack and support the vehicle by the frame. Note: Some auto makers recommend the use of a wedge to further relieve coil-spring tension (see drawing). Always check the repair manual for details before inspecting a front end.

MacPherson-strut-type suspension systems should be jacked at the frame during front-end inspections to unload the components you're checking out.

Once the car is properly supported, remember to grasp the tire at the top and bottom, and try to move the tire in and out to feel for side-to-side looseness. Then insert a pry bar under the wheel to check for up and down looseness. Always check the repair manual for the amount of free play that is permitted for a ball joint before condemning it, however, because some ball joints are supposed to move a bit. **P S**



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